METALLURGIA

THE BRITISH JOURNAL OF METALS.

MAY, 1934. VOL. X., No. 46.

Recent Developments in Lead

Outstanding advances have been made recently in the development of a lead possessing unique properties. By the addition of small proportions of tellurium to lead, a material has been produced which has the remarkable property of toughening when worked, possesses greater strength and increased resistance to fatigue than ordinary lead; and these properties are secured without sacrifice of the original valuable properties of the lead.

LEAD has been called the "precious metal," and so it is, if a metal's preciousness is measured by the number of its uses and its indispensableness in the goods that add to human comfort and welfare. Although exceeded in production by iron and copper, it is exceeded by iron only in diversity of usefulness and application. As a metal, an alloying agent, in chemical compounds, as an ingredient of manufactured goods, and an agent in industrial operations, the range of lead's usefulness is as wide as the field of industry itself. Lead is one of the oldest metals. As far back as B.C. 878 a king of Assyria took tribute in galena, and this ore was reduced by crude melting operations centuries before that date. The Romans conducted huge lead-mining operations in the Iberian Peninsula, and Pliny says they employed about

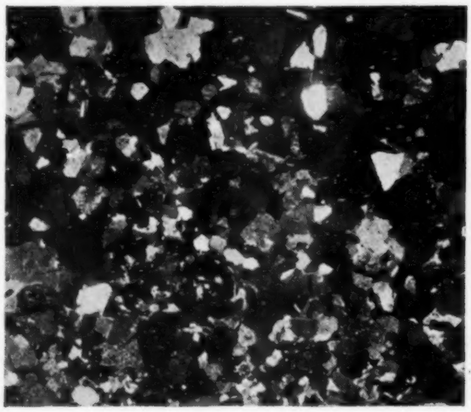


Fig. 1.—Chemical lead; shortly after rolling × 10.

20,000 slaves in the mines. Lead used up to comparatively recent times was superior to that in general use to-day, both in colour and durability, owing to the presence of small percentages of silver, which is now almost entirely removed. Recent developments, however, have resulted in the production of lead on a commercial scale which has an extremely fine and uniform grain structure, and has the capacity to toughen when strained—features which were formerly considered impossible of attainment.

It is well known that lead when pure is soft, plastic and viscous. It is almost non-elastic. Modern commercial lead is practically pure, due to the rigid refining it undergoes for the recovery of the silver. In the presence of air the surfaces of lead are quickly coated with a film of oxide, but this film increases very slowly. Pure water by itself is without action on lead; if air is present, however, a hydrated oxide is formed which is soluble. Further, if carbon dioxide is present, the process of lead corrosion and solution becomes a continuous one by precipitating the hydrate as carbonate as it is formed. Drinking water, however, is rarely chemically pure, as it generally contains small proportions of carbonate or sulphate of lime, which suffice to prevent this action. Nitrates and nitrites increase this process, whereas certain strengths of sulphuric acid have little action on lead, but when concentrated and heated, it forms the sulphate.

Owing to its chemical inertness and great power of resisting corrosion by moisture and atmospheric agencies, lead has a very wide application in many industries, not the least of which is the chemical industry, where it is applied to a considerable extent for lining vats, tanks, and for chemical works apparatus. In connection with the

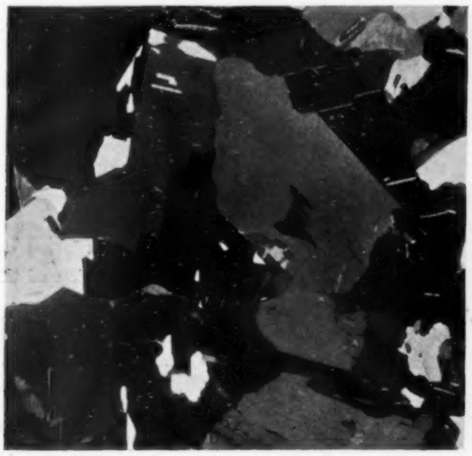


Fig. 2.—Chemical lead; after 1½ years' storage at room temperature × 10.

application of lead for chemical plant, W. Singleton[1] recently discussed developments which were achieved by the addition of small percentages of tellurium which have improved the mechanical properties of lead. These developments are the result of investigations undertaken because it was found that, in a very large measure, failures of lead in chemical plant can be traced to mechanical breakdown, which frequently takes place long before the lead has been seriously affected by corrosion.

It will be appreciated that for modern service a lead is demanded which is capable of withstanding more exacting mechanical and physical conditions than hitherto. Many alloys of lead with other metals are known which have much increased mechanical strength and resistance to failure by fatigue, but invariably these improvements have been obtained by sacrifice of some of the important characteristics which make lead so valuable a construction

1 W. Singleton, *Jour. Soc. Chem. Ind.* vol. LIII., No. 8, pp. 49T-52T.

material in the chemical industry. With even commercial lead, now obtainable in a very high standard of purity, the presence of small amounts of other metals when added to lead has been studied. Until recently, however, lead containing a small amount of copper was the only material of this class which had been used extensively in the chemical industry, but recently lead containing a small amount of nickel (of the order of 0·02% and less) has found application.

According to Singleton, opinion varies as to the merits or demerits of these materials in regard to resistance to corrosion, yet both have their advocates[2]; recent work has shown, however, that in neither case is there any marked permanent change in physical and mechanical properties of the lead. There is evidence that, although in the initial stages both products show refinement of grain, in neither case is re-crystallisation of the lead at ordinary temperatures inhibited, and both are prone to grain growth which frequently occurs in lead during service. Various workers, notably Werner,[3] have stated that larger grains increase corrosion, and that a refined grain is more desirable in a chemical lead. The latest work in this direction is in the addition of a small amount of tellurium to lead, which has been found to result in fundamental changes in the physical and mechanical properties of lead,[4] and the resulting product is one which has already proved of interest to the chemical industry, and to other users of lead. Lead containing tellurium of the order of less than 0·1% not only possesses markedly increased resistance to corrosion in certain conditions, but has a remarkably refined grain structure, much finer than that produced by either copper or nickel. It has also been found that the addition of tellurium to lead appreciably raises the temperature of re-crystallisation, so that tellurium lead is capable of being cold worked, and, in fact, becomes toughened when worked. In addition, not only is the grain of tellurium lead initially fine, but it remains in that condition, and grain growth which normally occurs in ordinary lead does not take place. The degree of toughening in tellurium lead sheet can be controlled, and it is therefore possible to produce tellurium lead sheet either in the soft or toughened condition.

Tests carried out show in Table I. the relative strength of lead and tellurium lead sheet at 100° C. The results show that the ratio of strength of tellurium lead sheet to that of lead sheet is greater at 100° than at ordinary temperature; the significance of this observation in respect of chemical plant is obvious. Further tests have been carried out on extruded ordinary lead, and extruded tellurium lead. Specimens of each were overstrained 12½% in tension, and then tested at various periods, after being allowed to rest in a condition free from stress at room temperature, the results of which are given in Table II. These results show that, although the strength of lead is increased after three minutes, it then commences to decrease, until after six months' interval, the strength is 12% less than the original value. Extruded tellurium lead, on the other hand, shows a considerable increase in strength after three minutes, and the increase continues to develop over the period of six months, when it has reached a strength 21% greater than the original value, showing that strain develops strength in tellurium lead.

As a structural material for the chemical industry lead has two peculiar features of fundamental importance: the grain size is liable to, and does, in fact, vary within wide limits; and it is markedly susceptible to grain growth and re-crystallisation at ordinary temperatures. Obviously, a structure containing grains which vary widely in size does not behave uniformly under strain, and in such cases metals are predisposed to inter-crystalline cracking. No definite grain size can be ascribed to ordinary lead, since grain growth is usual and variable both in service and shortly after rolling. Some indication of the grain growth occurring in chemical lead is illustrated in Figs. 1 and 2, the former showing the structure shortly after rolling, whilst the latter shows the grain growth after 18 months' storage at ordinary room temperature in a laboratory. By comparison with Figs. 3 and 4, which show the structure of tellurium lead under similar conditions, it will be noted

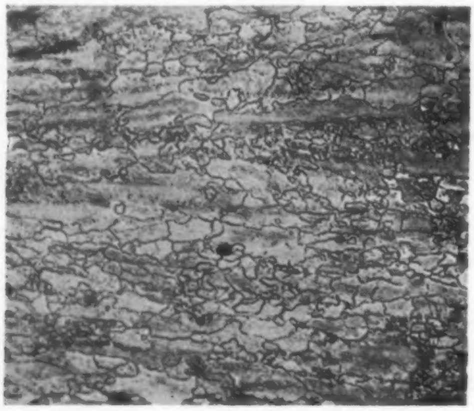


Fig. 3.—Tellurium lead; shortly after rolling × 50.

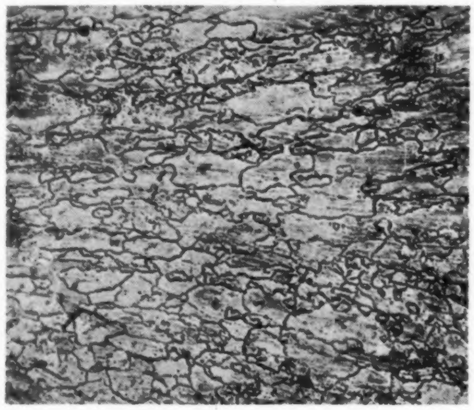


Fig. 4.—Tellurium lead; after 1½ years' storage at room temperature × 50.

NOTE.—The higher magnification of the tellurium lead was necessary for clear definition.

TABLE I.

Tensile strengths of lead and tellurium lead at 100°. Rate of elongation 0·022 in./in./min.

	Lead sheet.		Tellurium lead sheet.	
	Tensile strength, lb./in.²	% Elongation on 6 in.	Tensile strength, lb./in.²	% Elongation on 6 in.
"As received" at 15°	1570	49	2700	48
"As received" at 100° ..	804	51	1700	43
After 24 hrs. at 100°	765	46	1670	47
After 100 hrs. at 100°	820	50	1610	38
After 200 hrs. at 100°	730	54	1610	33

TABLE II.

Tensile tests on lead and extruded tellurium lead at different intervals of time after straining to an extent of 12½% beyond the elastic limit. Speed of pulling 0·25 in./in./min.

	Lead.		Tellurium lead.	
Condition.	Tensile strength, lb./in.²	% Elongation on 2 in.	Tensile strength, lb./in.²	% Elongation on 2 in.
"As received"	2530	64	2960	77
3 min. after straining ..	2800	48	3350	63
1 hr. after straining ..	2340	78	3330	62
24 hrs. after straining	2285	83	3380	60
7 days after straining ..	2240	108	3400	61
28 days after straining ..	2240	117	3500	62
6 months after straining..	2225	109	3590	62

Note.—The figures given in this table are only comparable with others obtained at the same speed of pulling.

2 Barrs, *Jour. Soc. Chem. Ind.*, 1919, 38, 407T. McKellar, *ibid*, 1921, 40, 137T. D. W. Jones, *ibid*, 1920, 39, 221. Mahin and Wilhelm, *Ind. Eng. Chem.*, 1930, 22, 1397.

3 *Z. Metallk.*, 1930, 22,342.

4 Singleton and Jones, *Jour. Inst. Metals*, 1933, 51, 71.

that no appreciable grain growth has occurred. It is known that the grain growth in lead is accelerated at elevated temperatures and by strain, and Figs. 5 and 6 show grain growth occurring in lead as a result of heat-treatment at 250° for one hour, compared with that of tellurium lead after similar treatment.

Fig. 5.—Chemical lead after one hour at 250° × 10.

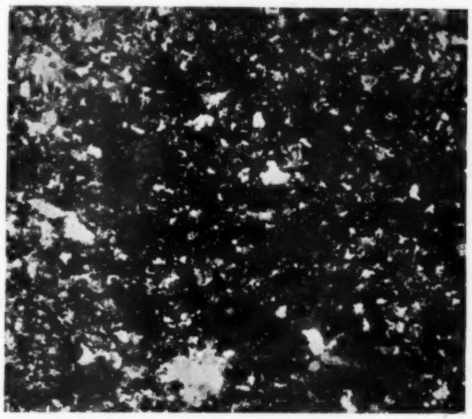


Fig. 6.—Tellurium lead after one hour at 250° × 10.

During the period of instability which exists in lead under strain, certain grains assume like orientation, so that grain growth occurs by reason of the formation of larger grains from the remains of smaller ones, and in such circumstances the grain boundaries are in an unstable condition; the knowledge that inter-crystalline cracking is the most common mechanical form of breakdown is an indication of this. Under stress the grains deform in certain well-defined directions depending on the direction of the stress and the resistance to deformation offered by adjacent grains. The degree of uniformity of the distribution of deformation depends to a large extent on the uniformity and size of the grains. Uniformity of grain size is not so important where grain size is small, since refined grain itself ensures more uniform distribution of deformation, but with large areas of very large grains with adjoining areas of very small grains stresses will not be uniformly distributed, and therefore the deformation will not be uniform. Since grain growth is a result of deformation, and the latter the result of strain, it follows that uneven distribution leads to uneven grain growth, and so the process proceeds, and therefore coarse-grained metal cannot as a whole respond to stress in a uniform manner.

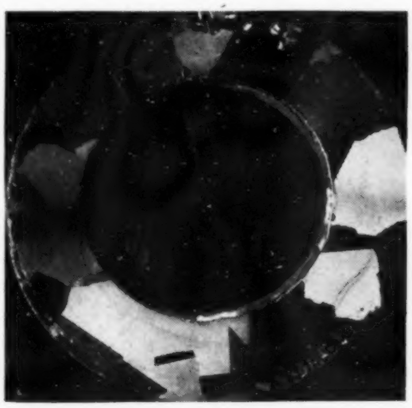
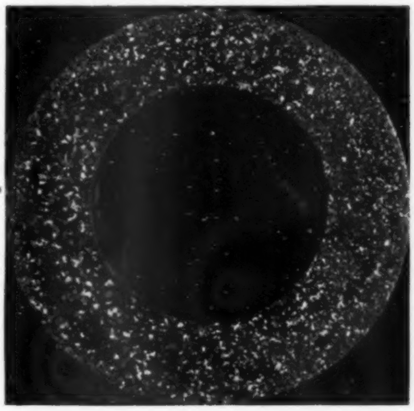


Fig. 7.—Coarse grain in chemical lead pipe after annealing at 250° × 3.
Fig. 8.—Non-uniform distribution of deformation of chemical lead pipe when strained. →



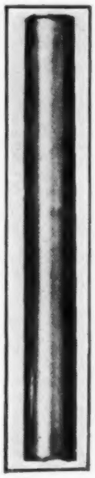


Fig. 9.—Refined grain in tellurium lead pipe after annealing at 250° × 3.
Fig. 10.—Uniform distribution of deformation of tellurium lead pipe when strained. →

The practical effects which result from the foregoing are illustrated in the comparative behaviour of chemical lead and tellurium lead, when subjected to strain. In the case of chemical lead, where the structure is irregular and variable in size, strains are unevenly distributed and are concentrated in certain grains. These grains re-crystallise, and favourable conditions for inter-crystalline cracking are established. In the case of tellurium lead, which has a refined and uniform structure, strain is much more evenly distributed, and the majority of the grains are affected, so that the concentration of strain which occurs in chemical lead is absent in tellurium lead, and the possibility of inter-crystalline cracking very markedly reduced. The coarse grain of a chemical lead pipe after annealing at 250° is shown in Fig. 7, while Fig. 8 shows the unequal distortion of the same pipe when strained. The refined grain of tellurium lead pipe after annealing at 250° is shown in Fig. 9, whilst the uniform distortion of the same pipe when strained is shown in Fig. 10. Both pipes were subject to precisely the same conditions.

There is a growing realisation of the importance of fatigue, or the effects of vibration on lead. In lead used in chemical plant, failures due to conditions of vibration are much more common than is often thought, and frequently arise from quite unsuspected sources. Instances are known where the proximity of a railway to a chemical works, or even the presence of a small electric motor, has produced a succession of failures in lead due to vibration. In the latter case, the removal of the electric motor was found to effect a cure, and further failures were not experienced. With the development of modern traffic and its attendant vibration, these conditions are becoming intensified in practically every instance where lead is used.

In the presence of vibration, failure by fatigue is always a possibility, irrespective of the type of structure. The resistance to fatigue appears to bear little relation to structure, as similar results have been obtained on both fine and coarse-grained lead. Tellurium lead has a resistance to fatigue approximately three times that of ordinary lead, a property which is obviously of considerable importance to the chemical industry.

The technical developments which have taken place in the use of tellurium lead in the short period it has been available on commercial forms are not altogether surprising when its unique properties are recognised. Singleton and Jones[5] show that not only has tellurium lead marked resistance to corrosion, but that its mechanical properties are entirely unique, for it is the first time that any form of lead has been discovered which has the property of toughening when worked. This feature alone makes it possible to use lead in a variety of circumstances where, hitherto, it could not be used satisfactorily. In addition to the property of work toughening, the material has a far superior resistance to fatigue than ordinary lead, and has not the disadvantage of hardness possessed by all other known alloys of lead with high fatigue resistance. One striking property of the material is that due to its fineness of grain; tellurium lead has a characteristic smooth surface, and the general appearance of lead pipes made from it indicates a superior finish to anything hitherto achieved.

Welds in Structural Steels

With greater knowledge of the basic principles involved in welding structural steels, the application of this process is rapidly increasing, but each new development necessitates further research in order to determine as accurately as possible the effect of different practice, and in this article brief reference is made to an investigation on the static and dynamic strengths of welds in structural steels.

THE chemical composition as well as the static and dynamic strengths of welds in structural steels made with different electrodes, have been investigated by W. Lohmann and E. H. Schulz. As parent metal was used two standard structural steels containing 0·13% copper (Din St 37 with a tensile strength of about 25 tons per sq. in. and Din St 48 with a tensile strength of about 35 tons per sq. in.), and two alloy steels containing about 0·7% copper and 0·4% chromium (Din St 52 with a tensile strength of 34 and 37·5 tons per sq. in., respectively). Single-V butt joints with full chamfer in plates 0·47 in. and 0·79 in. thick were welded, the total angle of the joint being 60°. After welding one side, the weld was shaped off at the same angle on the other side and finish welded. The welds were made with unalloyed and alloyed (0·8% copper and 0·4% chromium) bare electrodes, and with unalloyed coated electrodes.

The carbon and manganese contents of the weld considerably decreased with nearly all the electrodes used. The loss in carbon seemed to be the heavier the higher the content in the electrode was. An increase in the two elements can be caused by diffusion from the parent metal, or is due to the presence of these elements in the coat material. The variation of the copper content was extremely small. The nitrogen pick-up from the air seems to be possible only in the presence of oxygen, and probably takes place with the aid of an oxygen compound. It is, therefore, the highest in the case of bare electrodes where oxygen and nitrogen have free access to the weld. The chemical composition of the electrode does not affect the nitrogen content of the weld.

At room temperature the tensile strength of the parent metal was attained by the welds in steel St 37 in all cases, whatever type of electrode was used. The strengthening effect of the nitrogen absorbed completely compensated the heavy loss in carbon and manganese. The welds in the steels St 48 and St 52 attained the strength of the parent metal only in the case when electrodes of suitable composition were used, such as the bare electrode containing copper and chromium, and a coated electrode with higher manganese content (0·46%). With increasing strength of the parent metal, the strength figures obtainable with one and the same electrode increase. This fact is probably due to the diffusion of strengthening elements (particularly manganese and copper) from the parent metal into the weld. The elongation is primarily dependent upon the position of the fracture and the ratio of the tensile strength of the weld to that of the parent metal. The total elongation decreased with decreasing strength of the weld. By annealing at temperatures above A3, the tensile strength decreased in all cases, the loss being dependent upon the type of electrode used. With increasing nitrogen content of the weld the loss in strength increased, because annealing brought about a coarsening of the nitrogen structure. At elevated temperatures the strength of the parent metal was attained by the welds in steel St 37 in all cases, whereas the welds in the steels St 48 and St 52 only showed 90% of the strength in the case when bare electrodes were used.

The impact strength (test piece with and without notch) is primarily dependent upon the nitrogen content of the weld. With the repeated impact strength, however, a similar effect could not be stated, the tensile strength of the weld being of greater importance. The endurance bending strength was higher with the welds made with coated electrodes. This fact is, probably, more due to the higher content of pores and slag inclusions than to the lower ductility of welds made with bare electrodes. The tensile strength of the parent metal has little effect upon the endurance bending strength. The latter can, however, be increased by planing the weld face flush. (*Archiv fur das Eisenhuttenwesen*, February, 1934.).

[5] Singleton and Jones, *loc. cit.*

High-Tensile Structural Steel.

A SUMMARY of tests carried out on "Chromador" steel was given in a paper by Mr. Gilbert Roberts before a recent meeting of the Institution of Mechanical Engineers in London. He claimed that this new high-tensile steel is economical for structures of moderate size—the increase in strength being about 50% and the extra cost between 15 and 20%. As a result of tests comparison was made between the elastic curves of Chromador and mild steels, on the strength of beams and struts, and on the application of high-tensile rivets. It was contended that high-tensile steel is not so useful for compression purposes as might be supposed, but Mr. Roberts claimed that high-tensile steel showed considerable superiority for the range of struts most frequently used in practice. In building work, he declared, high-tensile steel was more advantageous in columns than in beams and girders. Referring to the use of high-tensile steel rivets, he said the full advantages of designs in this type of steel could not be obtained unless a rivet material of proportionately increased strength was employed.

Holding that the working stresses used for mild steels have no theoretical justification, but are based on accumulated experience, he discussed standards by which the relative usefulness of various steels can be compared. For Chromador steel he claimed that stresses varying from 11·25 to 13·3 tons per square inch had been used and advanced 12 tons per square inch in compression and bending as a reasonable working stress. This was comparable with 8 tons per square inch at present used for mild steel.

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PLANNED REORGANISATION OF INDUSTRY.

WE are passing through a period which is regarded as unique in the history of the world. It is a transition period of passing from one set of conditions which we understand, to a set we do not, and until we understand it we shall not progress very far. The new conditions are so complex that they seem to be beyond normal intelligence, yet the sooner they can be thoroughly understood the better their significance will be grasped, for this transition period is undoubtedly a critical one which is not only affecting one nation or one group of nations, but the whole of the world, and therefore makes us assume that we shall never get back to the positions we formerly occupied. Every month it is becoming more and more evident that no country's problems are merely its own, and that no nation can live unto itself. Despite this recognition, however, nationalism is becoming increasingly intensified, and normal international trade is being restricted to a degree that is crippling development and checking progress.

The frequency with which Japan appears in the news, indicates that that country's problems are not merely her own. Japan is half the world away, yet we know that what is happening in Japanese homes, offices, workshops and factories is having an effect on the daily life, not only of the inhabitants of Britain, but of the whole industrial world. Japan is in the news because she is affecting us both politically and economically. Actually her population is increasing at a very rapid rate, and it must be fed and clothed. Much of Japan cannot be tilled, and it is not unnatural that she should strive by all means in her power to increase markets for her products, in order to meet the demands of her growing population.

Japan's Industrial Revolution.

In many respects Japan is not unlike Britain, for each country must export its products to obtain essential food and raw materials, which can only be produced, or are available in these countries on a very limited scale. The main difference between them is that Britain realised the need for world trade long ago, and, in the modern sense, is one of the oldest industrialised countries. She made so much progress in years past that she was looked upon as the world's provider, and her people as a nation of shopkeepers ; Japan, in fact, was a good customer of hers, but, during comparatively recent years the Japanese have become industrialised, and have made so much progress in various directions that, in addition to meeting home demands, they are penetrating overseas markets with their products to a remarkable degree. It is primarily her growing population however, that has caused Japan to fight the Chinese in Manchuria, and the European nations in the markets of the world. Nationalism is being fostered on an unprecedented scale, and as one Japanese authority states, the industrial revolution in Japan is proceeding with terrific momentum, due in part to a remarkable power of organisation, but also to the pressure of a steadily increasing population, for which there is no satisfactory outlet. The necessity of colonial expansion is felt to the utmost intensity and driven by this need, the average Japanese is quite prepared to cast idealism to the winds on the principle that necessity knows no law. The grasping policy of the recent "hands off China" declaration may be regarded partly as a feeler to enable the Japanese authorities to gauge how far further attempts at aggression would be tolerated by the other Powers. But for the other nations it is a definite indication of the way the Japanese wind is blowing. It is obvious that Japan is not satisfied with attacking Shanghai and the domination of Manchuria ; it is probable, indeed, that her ultimate aim is complete control of the Far East ; but, however true it may be that necessity knows no law, where there is no recognition of the moral law, there can be no possibility of peace either politically or industrially.

Five Years' Plan.

This reference to Japan is simply one aspect associated with new conditions that now exist ; but this problem of finding markets to absorb surplus labour is not confined to Japan, it is a very pressing problem with all civilised nations. In Britain, for instance, although her unemployment figures are declining, there are still over two millions unemployed, and, as Mr. Angus Watson points out, in a thoughtful letter published in *The Spectator*, these, in large numbers, are made up of comparatively young citizens, who have never been able to look out on life with any sense of security. A large proportion of them are educated young men, capable and eager, who cannot find an opening of any kind at home, and to whom no other nation will extend a welcome. Before the war, emigration would have solved this problem, but to-day nearly every foreign or colonial market is closed to them. It is suggested that Britain should prepare a five years' plan, during which long overdue constructive work could be put in hand on a national basis: for this purpose a National Service Army should be created. Since the Armistice it is claimed that about 1,500 million pounds has been spent in entirely unproductive expenditure in maintaining the unemployed. The fruit of this expenditure has been national demoralisation of character, and the destruction of self-respect. A fraction of this amount spent during the next five years, it is claimed, would not only be fruitful, but would bring new hope to the great army now regarded as surplus labour.

Remove Antiquated Industrial Restrictions.

This suggestion of a five years' plan is an admirable one, but it should not be confined to the preparation and putting into execution of a comprehensive scheme of development work in every area, a complete industrial survey should be included and steps taken to organise industries in the light of present conditions. So many anomalies exist to-day as a result of accumulated precedents and experience that it is impossible to carry on the basic industries economically. Nations such as Japan, that have only recently industrialised, are not concerned with precedents ; they have organised their factories with full knowledge of the weakness of methods adopted in this country. We on the other hand are tied down to practices that doubtless were necessary a decade or half a century ago, but which are no longer applicable to modern conditions. It is not only organised labour that tends to hold up the proper organisation of industry, employers are in a measure responsible. Commissioners have been sent to the most depressed areas with the object of getting the root causes, but if industries were properly organised, all those pettifogging restrictions

removed, and the straight-line system of manufacture and sale adopted, there would be less need to report on depressed areas. Properly organised and equipped with modern machinery, the various industries would be in a position to compete in the world markets on favourable terms with other nations.

Industry's Obligation.

The British National Government has done much to promote soundness during a very difficult period, but there is a grave danger in the feeling of complacency which seems to exist. It is not suggested that the Government should organise industry, but it can force capital and labour to prepare comprehensive reorganisation schemes for each industry, just as has been done in the case of the iron and steel industry. The majority of the industries have now been protected; the main object of the tariffs was to facilitate reorganisation, instead of which the shelter afforded the industries has apparently reduced the need. There is an obligation to put the industries on a proper economic basis, in which condition they should be in a position to compete favourably with similar industries of other nations, and the Government can force action on these lines by each industry.

Protection is not a cure in itself, nor are quotas or any other form of trade restriction; they should be regarded as a temporary expedient, necessary during the transition period through which we are passing, to enable industries to organise in accordance with the new conditions existing. Create a National Service Army and prepare a five years' development scheme, but take effective means to ensure that the industries primarily concerned with overseas trade are thoroughly efficient and adopt the most modern marketing methods, for ultimately it will be realised that the freer interchange of commodities between nations would solve many of the world's present difficulties and provide increasing work for the surplus labour in all countries organised to undertake it. No country can afford to develop haphazardly, and Britain, which depends so much on overseas trade, least of all; it is imperative therefore, that ordered schemes for reorganisation should be planned and put into operation without delay.

The American Debt.

It is very unfortunate that the question of debt payment to America has again arisen. Obviously a sane settlement of this vexed question would have a considerable effect on the peace and prosperity of the world. Apparently it has become associated with domestic politics in America, but its effect is to raise grave issues in world politics. It seems that even though the British Government offers a token payment to the United States on account of the debt, the British Government will be regarded by Washington as a Government partially in default and treated as a defaulting nation.

The outlook for June 15, when the payment is due, is very confused, because what the British Government is prepared to offer is not known; actually no provision was made in the Budget for any payment to America; certainly it is very questionable indeed whether it can accept the suggested scheme of payment by Finland as a guide. Such a settlement would be based upon the cancellation of interest charges; with such adjustments the British obligation would still amount to about £400,000,000, the payment of which is impossible. To attempt to pass this debt on to those nations responsible for its payment would also be futile; it is hoped, therefore, that saner counsel will be accepted, and a real effort made to reach a solution to this controversy which would be acceptable to all parties. The stirring up of this controversy, which was peacefully dying, can do no good to any nation, and the sooner an amicable settlement is effected the better it will be for the peace of the world.

THE ROYAL AERONAUTICAL SOCIETY.

The lecture by M. Louis Breguet has been postponed until October of this year.

Forthcoming Meetings

THE IRON AND STEEL INSTITUTE.

The Annual Meeting of the Institute will be held at the Institution of Civil Engineers, on May 31 and June 1. The programme of technical papers to be presented is as follows:—

May 31. *Morning Session.* "An Experimental Enquiry into the Interactions of Gases and Ore in the Blast-Furnace. Part III.—Proposed Methods for Comparative Testing of Iron Ores," by W. A. Bone, F.R.S., H. L. Saunders, and N. Calvert. "An Experimental Enquiry into the Interactions of Gases and Ore in the Blast-Furnace. Part IV.—Equilibria and Velocities in Ore Reduction," by W. A. Bone, F.R.S., H. L. Saunders, and J. E. Rushbrooke. "The First Report of the Blast-Furnace Practice Sub-Committee," to the Iron and Steel Industrial Research Council. "Blast-Furnace Linings. Part I.—An Examination of the Information Received in Reply to a Questionnaire Circulated to Iron Manufacturers," by A. T. Green. "Part II.—Some Properties of the Fireclay Products Used for Blast-Furnace Linings," by A. T. Green, W. Hugill, F. H. Clews and H. Ellerton. "Principles of the Design of Blast-Furnace Lines," by J. J. Sarek.

Afternoon Session (2-30 p.m.). Presentation of the following papers for discussion:—"The Elasticity Deflection and Resilience of Cast Iron," by J. G. Pearce. "Tin-Iron Alloy in Tinplate with Notes on Some Imperfections," by W. E. Hoare. "A Microscopic Examination of Iron-Tin Reaction Products," by W. D. Jones and W. E. Hoare.

June 1. *Morning Session* (10 a.m.). "Second Report of the Corrosion Committee," to the Iron and Steel Industrial Research Council. "The Manufacture of Full-finished Steel Sheets," by E. R. Mort. "The Behaviour of Sulphur in Open-hearth Furnace Gases," by E. Maurer and W. Bischof.

Afternoon Session (2-30 p.m.). "Dendritic Segregation in Steel Ingots," by L. Northcott. "A Study of Ingot Structures," by L. Northcott. "Periodic Structures in Metals and Alloys," by L. Northcott. "The Effects of Cold-Rolling on the Intergranular Corrosion of the 18/8 Austenitic Steels," by E. C. Rollason. "The Thermal Conductivity of Tool Steel," by D. Hattori.

INSTITUTE OF BRITISH FOUNDRYMEN.

The thirty-first Annual Conference of the institute will be held at the Midland Hotel, Manchester, from June 5 to 8, 1934. It is 12 years since Manchester was honoured by the Annual General Meeting of this organisation, and, since the arrangements are in the hands of the members of the Lancashire Branch, members and their friends who attend this meeting can be assured of having an interesting and enjoyable time. Every effort is being put forth to make the conference valuable, both technically and socially. The programme of papers to be presented at this meeting is as follows:—

June 6. *Morning.* Report of Cast Iron Sub-Committee of the Technical Committee. "The Crystal Structure and Formation of Graphite in Cast Iron, and Their Influence on the Properties of the Casting," by Dr. Ing. Heinrich Nipper (Presented on behalf of the Verein Deutscher Eisengiessereien.)

June 7. *Morning.* Session A.—"The Drying of Moulds and Cores," by E. G. Fiegehen, M.I.Mech.E., of Canada. "Recent Developments in British Moulding Sand Practice," by J. J. Sheehan, A.R.C.Sc. "The Use of High Quality Cast Irons in the Construction of Textile Machinery," by M. Roeder, Société Alsacienne Constructions Mécaniques. (French Exchange Paper.)

Session B. "The Properties of Cast Red Brass as Affected by Conditions of Casting and Impurities," by C. M. Saeger, Jr., United States Bureau of Standards. (American Exchange Paper.)

"Effect of Mass and Composition on Sand Cast Bronzes," by F. W. Rowe, B.Sc.

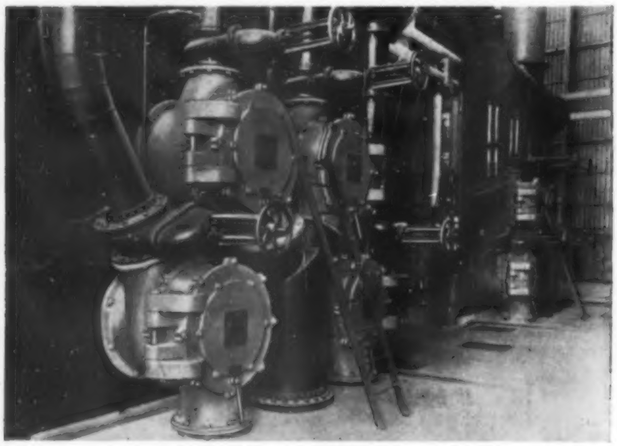
A full day's excursion arranged for June 8 will give members and their friends an opportunity of spending a few hours in some of the most beautiful scenery in North Wales, and will also afford the opportunity of inspecting the old City of Chester.

BLAST-FURNACE GAS FIRING.

UNTIL a few years ago surplus blast-furnace gas had largely been used in the most unscientific fashion for heating steam boilers, often of the "Lancashire" type, equipped with crude non-turbulent long-flame burners, and many iron and steel works are still operating on these lines. However, times are changing, especially since the adoption of modern methods of cleaning blast-furnace gas which enable it to be used direct both for steam boilers and by-product coke ovens, as well as for mixing with coke-oven gas, and the operation of metallurgical furnace settings of all types.

The use of turbulent short-flame burners for blast-furnace gas, as well as any other gaseous fuel such as coke-oven gas and producer gas is, however, claimed to be essential if the best results are to be obtained, whether using dirty or clean gas.

In this connection of great interest, as an example of the latest methods, is an installation of two high-pressure water-tube boilers in an iron and steel works equipped with "Gako" burners, using blast-furnace gas supplied at a



Two water-tube boilers fired with turbulent burners using blast-furnace gas.

pressure of 2" W.G., the air also being at the same pressure. The boilers each have a heating surface of 43,000 sq. ft., operating at 360 lb. per sq. in. pressure, with a normal evaporation of about 44,000 lb. of water per hour.

In general it may be remembered the "Gako" burner, a product of Liptak Furnace Arches, Ltd., of London, supplied in a number of types according to the conditions, has the gas and air supplied to the burner casing by separate pipes under accurate valve control. Both the gas and the air are given, by means of suitable guides and passages, a pronounced whirling motion so that on meeting rapid and powerful mixing takes place, on the turbulent principle, and combustion is completed in a very short flame quite different from the ordinary non-turbulent burner. The design also is such that the front cover can be swung open on hinges for immediate examination and cleaning in the case of stoppage because of dirty gas, the disconnecting of pipes being unnecessary. Efficient operation, however, even with the most dirty gas, is given in remarkable fashion, and whilst the cover is opened the burner can still operate with air supply at atmospheric pressure.

The various modifications in the standard design have been introduced to cover every condition of operation, including air pressure, gas pressure, quality of gas (mixed or otherwise), type of furnace setting, and exact duty required. They lend themselves also particularly well to the latest ultra-scientific methods of almost completely automatic control of steam boiler plant.

Cementation with Metal Carbides.

CEMENTATION experiments have been carried out by J. Gaeff, with the view to examine whether the carbon diffuses into the iron in the form of carbide or in the atomic state. The experiments were made with iron carbide, iron manganese carbide, iron chromium carbide, and tungsten carbide. Instead of the pure iron carbide, which is difficult to produce, a white charcoal iron was used containing 3·65% carbon, 0·28% silicon, 0·14% manganese, 0·014% phosphorus, and 0·02% sulphur. The iron manganese carbide, containing 75·8% iron, 17·72% manganese, and 6·83% carbon, was mechanically picked from spiegeleisen. The two chromium carbides were made in the high-frequency induction furnace, and contained 48% iron, 44% chromium, 7·34% carbon and 2·3% iron, 87·37% chromium, 10·15% carbon, respectively. The tungsten carbide was obtained by cementation of tungsten powder in town gas and subsequent annealing in carbon monoxide at 1,500 to 1,600° C.

A mild steel cylinder of 0·8 in. dia., into which a hole had been drilled, was filled with the finely powdered carbide, and after being plunged, annealed at temperatures from 700 to 1,100° C. for 10 hours. After cooling in the furnace the cylinder was cut through and the depth of carbon penetration was determined under the microscope.

The temperature at which cementation began was different with several carbides. It was found to be at about 700° C. with the charcoal iron, 750° C. with the iron manganese carbide, 850° C. with the iron chromium carbide, 900° C. with the chromium carbide, and 940° C. with the tungsten carbide. The temperature-depth of penetration curves have a slightly curved form, with the exception of the curve obtained with iron chromium carbide as cementation medium, which is a straight line. All the curves, however, lie below the curve which is obtained when cementation is carried out with elementary carbon. In the structure of the cemented steel cylinder several zones could be detected, the formation of which is due to the fact that the carbon atoms of the carbide travel faster into the iron than the metal atoms. The experiments show that the diffusion of carbides as such is not possible, even though the several components are soluble in δ-iron. Cementation can only begin after the dissociation of the carbide, which takes place at a definite temperature. Once the carbide has decomposed, the carbon and metal atoms move independently with different velocities. (*Archiv fur das Eisenhuttenwesen*, April, 1934.)

Gases and Metal Surfaces.

THE twenty-fourth annual May lecture of the Institute of metals was delivered by Professor E. K. Rideal, F.R.S., in London, recently, in which he dealt with gases and metal surfaces. The reactions of gases with metals, said Professor Rideal, are important not only in metallurgy but also in a number of important chemical reactions, especially those termed catalytic, such as are involved in the production of synthetic ammonia or fuel oil. From a study of the adsorption of gases by metals, we can obtain some idea of the structure of the surface of the metal, and we find that metals do in fact contain numerous fissures and holes which affect the physical properties of the metal.

Cases can be held on to metal surfaces by at least two distinct methods, one by a purely physical attractive force, and the other where a species of chemical combination takes place between gas and metal. Each of these combinations possesses characteristic properties which can be examined and the conditions of the conversion of one form with the other can be explored. Adsorbed gases can move over the surface of metals by process of activated migration, analogous to hopping, and this hopping is found to play an important part in rates of reaction at surfaces. Metallic vapours when condensed as sponges possess remarkable properties which eventually disappear as the sponge collapses.

Non-destructive Tests

By E. C. Rollason, M.Sc.

(Lecturer in Metallurgy, County Technical College, Wednesbury.)

Non-destructive methods of testing are valuable as investigatory tests for improvements in the design or method of manufacture of an article, and the development of the application of a test which indicates the quality or soundness of an article without damage to it offers many attractions. The author discusses these tests.

THE usual mechanical tests are commonly conducted on selected samples assumed to be representative of the material and, consequently, the results are limited. In some applications, typified by castings and welded articles, tests cannot be applied which injure the article in any way. We can therefore divide testing into two main groups according to the action on the tested material. These are destructive testing and non-destructive testing. This article is concerned with the latter group, which may be classed into magnetic and electro-magnetic tests, acoustic tests, and radiographic tests.

Magnetic Tests.

From work done at the United States Bureau of Standards, it is evident that the magnetic properties of ferro-magnetic substances are very closely related to the physical and chemical structure of the material. They are very sensitive to very slight changes in condition of strain or of structure, so that there is only one set of magnetic characteristics corresponding to a given set of mechanical characteristics. The latter may be considered as a resultant of the physical and chemical changes which have taken place throughout the manufacture of the material. Based on these facts, alternating current test methods have been developed for the examination of wire, tubes, and bars, limited to a maximum of 4 in. diameter, on account of the "skin effect." The sample of material is passed slowly through special coils which consist of two windings—primary and secondary—acting as step-down transformers.

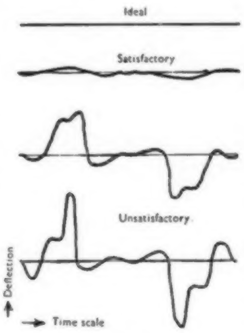


Fig. 1.—Types of oscillograph records.

Now it is known that if the current passing through the primary of a given coil is constant, any variations in the wave-form of the current induced in the secondary winding must be due to the structural variations in the core of the solenoid—*i.e.*, the bar under test. In practice two identical coils are used together. The primaries are joined in series and connected to a source of alternating current. The secondaries are also connected in series with each other, but one is wound in the same direction as its primary while the other is wound in the opposite direction to its primary. The net result is that with an air core the current from one secondary is exactly equal to that coming from the other secondary, but it is of the opposite polarity.

The same results should be obtained by inserting as cores two specimens with identical magnetic properties. In actual practice there is a slight sinusoidal curve of small amplitude instead of a straight line. On the other hand if a defective specimen is substituted for one sample the currents from the two secondaries will be different in value, and the result will be a distortion of the sinusoidal wave form, the degree of distortion indicating the extent of the structural variations.

Typical wave-form diagrams are shown in Fig. 1. These are reproduced by an oscillograph which consists of vibrators (highly damped vibration galvanometers) fitted with reflecting mirrors. A beam of light is reflected from these on to a photographic film carried by a revolving drum, or, alternatively, on to a screen by means of a second mirror oscillated at right angles to the first by a synchronous motor. This movement provides the time scale.

Now, the principles indicated above can be applied in two ways, as shown in Fig. 2.

1. The same bar can be passed through the two coils consecutively. In other words, each portion of the bar in coil (*a*) is compared with that portion of the same bar which is in coil (*b*). A distorted wave-form diagram indicates lack of uniformity in the bar. This method is useless if the flaw is continuous throughout the length of the bar.

2. The bar of unknown characteristics can be passed through coil (*c*), which is connected to coil (*d*), containing a standard specimen. This gives a comparison with a standard established by other tests.

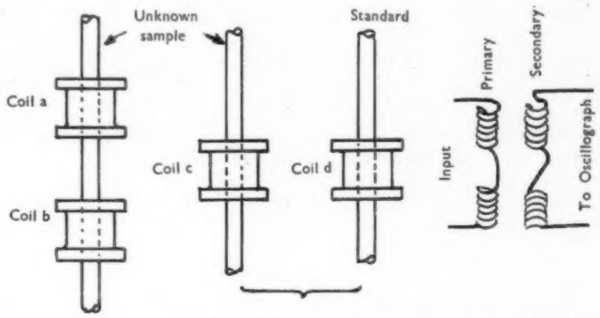


Fig. 2.—Diagram showing arrangement of coils for magnetic analysis.

The test can be applied to hardened and tempered specimens and for the separation of mixed material; to the testing of welded tubing and drawn rods to indicate soundness and freedom from cracks.

The G.E.C. of America have developed a somewhat similar method, using high frequency current. Two coils are coupled together and connected through an amplifier to a loud-speaker or indicator. The coils are tuned to the same frequency and the material is passed through them. A flaw changes the induced current, which then alters the note from the speaker or deflection of the indicator.

Magnetic Dust Method.

The test was first indicated by Major Hoke and developed by Roux and by Watts. The principle underlying the test is the fact that iron filings which are comparatively free to move show the lines of magnetic force, and always tend to collect at the pole-pieces of a magnet. Now, if a magnetic flux is passed through iron or steel the presence of a crack lying across the path of the flux will cause magnetic poles to appear at each side of the crack. These poles attract the iron filings, the accumulation of which indicates the crack in the article.

There are several variations in carrying out the test. The magnetisation may be either permanent or temporary, and yoke or circular method employed. In one application the article is placed between the poles of an electro-magnet,

and a sheet of paper above it is sprinkled with iron filings or dust. The faults are shown by the masses of filings. A photograph can be taken or the filings fixed into position by spraying with gum solution, or by employing waxed paper which is warmed after filings are in position. Alternately, blue-print paper can be used and exposed to a portable arc lamp, thus giving a contact print.

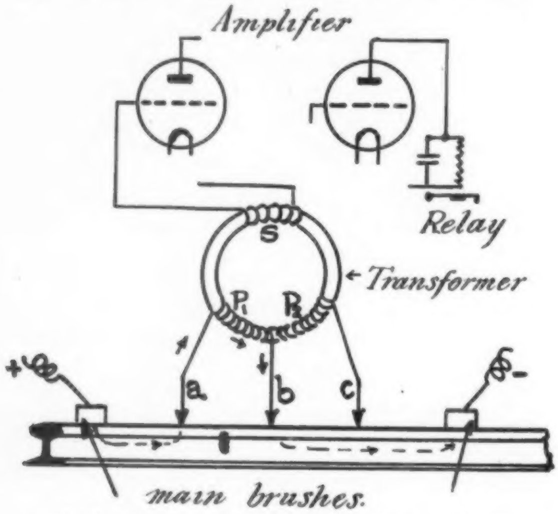


Fig. 3.—Arrangement of Sperry Electro-magnetic test.

Another procedure is to magnetise the article and then immerse in a bath of kerosene, containing about 3 oz. of fine soft iron dust per gallon. The dust is relatively free to move and adheres to any crack in the article. Naturally, it must be very fine in order to keep it in suspension, and it can be conveniently prepared by reduction of the iron oxide with hydrogen. In addition, the oil should be freed from moisture with calcium chloride.

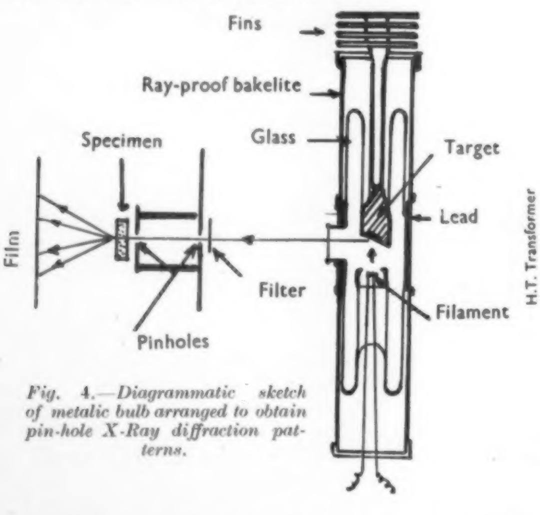


Fig. 4.—Diagrammatic sketch of metalic bulb arranged to obtain pin-hole X-Ray diffraction patterns.

It will be seen that the test is very suitable for detecting cracks in heat-treated products, forgings, ground surfaces, and the physical defects, such as seams, laps, etc., in rolled bars and seamless tubing.

Electro-magnetic Test.

In 1929 E. A. Sperry* described a method he had devised for the detection of transverse fissures in rails, and it was claimed to be applicable to all metals and alloys in the form of bars, plates, tubes, and welded joints. It would appear that fillet welds would offer some difficulty.

Essentially, the Sperry method, as applied to rails, consists in mounting the apparatus on a small railway car which travels along the track under test. Two main brushes (Fig. 3) make contact with the rail and allow a heavy direct current to be passed through the portion of the rail between the brushes. Between these brushes are

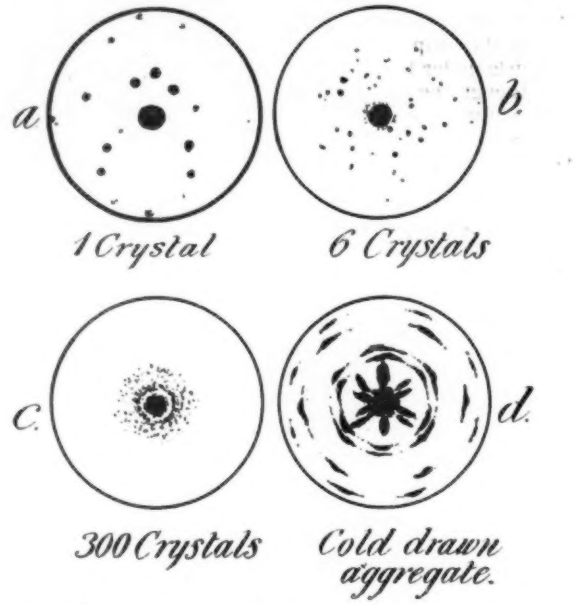


Fig. 5.—Sketch of diffraction patterns for aluminium: (a), (b), (c) indicate the effect of superimposed grains; (d) shows the effect of preferred orientation or fibre.

located three searching brushes connected to two coils constituting the primary of a transformer. These coils are identical but wound in opposite directions, so that with equal currents the secondary coil is not influenced. When

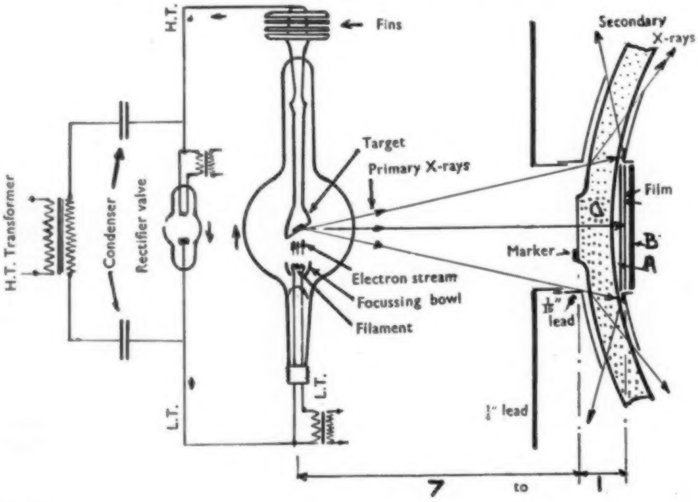


Fig. 6.—Diagram showing the arrangement of the Villard circuit, tube and lead shields in the X-Ray inspection of metallic articles.

a fissure occurs between one end brush *a* and centre brush *b*, coil P_1 will become excited to greater extent than coil P_2, due to the greater resistance of length *ab* relative to length *bc*, and the transformer becomes active.

A similar E.M.F. with opposite polarity is induced when the fissure passes between *b* and *c*. This induced E.M.F. is amplified by a set of four radio valves with a step-up of two 300,000 times, and then operates a relay working in conjunction with a pen for recording purposes. In addition, there is the measurement of magnetic potential

* Am. Soc. Steel Treating, Vol. 16, p. 771.

drop, and of the electrical potential drop across a portion of an article as developed by Spooner and Kinnard.

Acoustic Tests.

This is simply a refinement of the test adopted by workmen of striking a piece of metal in order to determine whether it "rings true." A medical stethoscope fitted with a rubber cap over the conical end is pressed against the article under test, which is lightly tapped with a hammer. Although the test is attractive on account of its simplicity, it requires a good deal of experience before the results are reliable.

X-Rays.

X-Rays are now regarded as ether vibrations which originate at a dense substance (anticathode or target) when it is struck by a stream of electrons or negatively charged particles.

In the original type of X-Ray bulb the particles were obtained from the small amount of gas left after evacuation. In the newer type of bulb the particles are shot from a heated filament. In both cases the speed of the electrons and, consequently, the hardness of the X-Rays, increases with higher voltage between the cathode and anticathode.

These rays travel in straight lines and are capable of penetrating matter which is opaque to ordinary light. The absorption is roughly proportional to the density of the substances, so that lead is opaque relative to aluminium for given X-radiation. This radiation affects photographic plates in a way similar to light, and causes certain substances, typified by barium platinocyanide, to fluoresce, so that both of these properties are employed to detect varying intensities of X-Rays.

X-Rays vary in their ability of penetrating substances, so that hard X-Rays having very short wave-lengths are required when metals are being investigated. This necessitates steady high voltages (of the order of 100-200,000 volts) which offer many difficulties in the design and operation of the plant. The frequency of the X-Rays, or, in other words, the hardness, varies also with the material of the target, but at low voltages the radiation is of a general character made up of very different frequencies.

When the voltage is increased to some critical value for the anticathode, a characteristic radiation is emitted which depends entirely on the material, so that we speak of molybdenum-rays, iron-rays, etc. In other words, most of the energy is emitted on a narrow band of wavelengths with less intense secondary peaks.

These latter peaks can be reduced by means of filters, but the total intensity is reduced and it becomes a compromise between monochromatic radiation and intensity.

X-Rays can be employed in two ways for testing purposes.

Debeye and Scherrer Method.

The first is a modification of Laue's experiment in which a heterogeneous X-Ray beam was passed through a single block crystal, with the result that a symmetrical design of spots was revealed on the photographic plate due to reflections from different avenues of atoms. The method consists in passing a beam of heterogeneous X-Rays, defined by pinholes, through the material (Fig. 4) so that the resultant photograph shows the Laue patterns of a chaotic aggregate of small crystals superimposed on each other, as shown diagrammatically in Fig. 5. With monochromatic radiation a concentric ring pattern is obtained.

Cold working the specimen produces a non-symmetrical effect due to the elongation of the spots, which is termed asterism. This indicates a state of internal strain. Further cold work produces a symmetrical orientation pattern, indicating that the crystals are oriented in a definite fashion. Such a structure is termed fibring and is indicated in Fig. 5c.

This method reveals details about the metal itself, such as grain size, orientation, internal strain, and recrystallisation. The next method only indicates the soundness of the metal, but is much more easily carried out. In fact, it is possible to conduct the work in the workshop, whereas the first method is as yet a laboratory process.

Radiography.

This method consists in passing a beam of heterogeneous X-Rays through the object and studying the shadow formed on a fluorescent screen for thin sections, or on a photographic film placed at the back of the object. Blowholes, cracks, etc., appear as dark areas on the negative, due to less absorption of the radiation, but as light areas on the positive print.

Defects equal to 2% of the thickness of the article can be detected, and this sensitivity is checked by placing on the side of the article facing the X-Ray bulb a stepped piece of steel, each step varying by 1 mm. Lead numbers placed on the side of the article are used for identifying the positions of the radiographs.

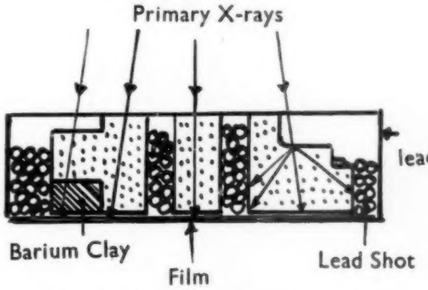


Fig. 7.—Sketch showing the method of blocking out holes.

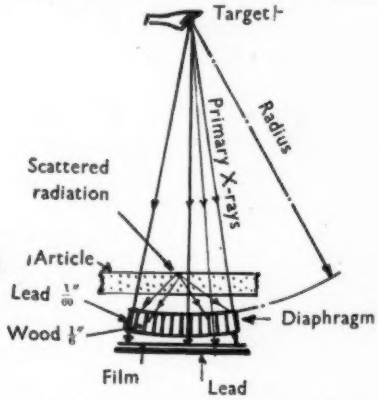


Fig. 8.—Diagram of Potter-Bucky diaphragm arranged to prevent the fogging effect of scattered X-Rays.

The modern apparatus for the production of X-Rays consists of an X-Ray bulb of the hot cathode type operated by a high tension transformer with valve rectifier. Diagram 6 illustrates the arrangement. The introduction of the self-protected and shock-proof tubes (*e.g.*, Phillips' Metalix) has symplified the problem of protecting the operator, and at the same time facilitated the transportation of the apparatus to different parts of a works.

In the last few years the exposure times have been reduced by (1) better equipment (high voltage bulbs, etc.); (2) contrivances for improving quality. A few of the latter can be mentioned.

(*a*) The use of thin lead foil in the film holder, as indicated in Fig. 6, Piece (A), acts as a filter, and both (A) and (B) act as intensifying screens by converting the short-wave X-Rays into longer waves which affect the photographic emulsion to a greater extent.

(*b*) The use of intensifying screens in contact with the film. These screens are coated with calcium tungstate, which is capable of transforming the energy of the X-Rays into visible and ultra violet light to which the film is more sensitive.

(*c*) To eliminate the fogging effect of the scattered X-Rays lead sheet can be employed for blocking out flat portions, while lead shot can be used to fill holes (illustrated in Fig. 7). In other cases the Potter-Bucky diaphragm may be interposed between object and film. This consists of alternate strips of wood and lead arranged parallel to the primary X-Rays. The secondary rays spread out at greater angles than the primary rays and are absorbed by the lead as indicated in Fig. 8.

Articles consisting of thick and thin sections, or having surface blowholes can be immersed in solution having an absorption coefficient slightly less than that of the specimen, such as 20-35% barium chloride for aluminium. In the absence of internal defects a uniform shadow is obtained.

The depth of the defects can be obtained by taking two exposures from two different angles and calculating by a triangulation method.

Gamma Rays.

Whereas the application of X-Rays is at present limited to a maximum of about 4½ in. of steel, gamma radiation is applicable to 3-10 in. of steel, due to the very short waves, which have, however, the disadvantage of greater diffusion with consequent lack of contrast.

The gamma rays are produced by the decomposition of radio-active substances, such as radium or a gas from radium. The radium salt is stored in a small metal capsule, and articles to be tested are arranged round it. Films in holders are placed behind the articles and a shadowgraph obtained. Unfortunately, relatively large quantities of expensive radium are required and the exposure is of long duration —for example: 10 hours with 1 grm. of radium for 6 in. of steel 18 in. away.

In conclusion, it will be evident that certain methods of non-destructive testing are of great value in particular cases, especially as investigatory tests for improvement in the design or the method of manufacture of an article; but many of them require expensive apparatus and skilled operators. Nevertheless, the development of the application of a test which indicates the quality or soundness of an article without damage to it offers many attractions.

The "Velox" Steam Generator

New designs of steam generators have been developed, and improvements have been made in their equipment, but little has been done to modify the principle of steam generation. During recent years intensive study has been directed to the production of units of large output occupying the minimum of space consistent with the maintenance of high efficiency; this has led to the development of the Velox steam generator.

THE use of increased steam pressures and temperatures, and the continuously increasing demand for larger and larger units has, during recent years, led to an intensified study of boiler design, with the object of producing units of large output, occupying the minimum space consistent with the maintenance of high operating efficiency. Attention has been directed to the use of water walls, economisers, air heaters, etc., which have improved the performance of the water-tube boiler. New designs of steam generators have been developed, and improvements have been made in the design of stokers, in the application of powdered fuel, and the use of oil as a fuel has been further developed; little, however, has been done to modify the principle of steam generation, or to utilise the effects of increased flue-gas velocities as experimentally demonstrated by Nicholson in 1906.

Experiments carried out in 1928 showed that flue-gas velocities up to the velocity of sound (about 1,600 ft. per sec.) would enable steam generation at a very high rate to be obtained, and the use of such velocities, and the method of production based upon the experience obtained with gas turbine experiments—by exploding the fuel and air mixture in a closed chamber—was patented. Further experiments carried out with a steam generator built on these lines showed that highly satisfactory results could also be obtained if the fuel and air mixture, instead of being exploded, were burnt under constant pressure sufficiently high to ensure gas velocities through the flue tubes of between 600 and 1,600 ft. per sec.

Application of the gas turbine cycle indicated a possible way of obtaining the necessary pressure of combustion by using part of the energy contained in the flue gases themselves to obtain from a gas turbine the necessary energy for driving the required compressor. In the gas turbine of the Holzwarth type, for instance, the total heat of combustion can be considered as consisting of two parts, the greater part performing work in the gas turbine, the lower grade heat being used for the generation of steam. If the latter is only just sufficient to perform the work of compression, the steam turbine is simply used for driving the compressor and the gas turbine driving the generator supplies the useful energy. On the other hand the cycle can be modified by reducing the temperature limit of the gas turbine so that the gas turbine itself only supplies the necessary energy for compression, and the combustion chamber functions as the steam generator supplying steam to the steam turbine for the generation of useful energy. The steam generator can therefore consist of a combination of tubular evaporator elements surrounding a combustion chamber, with a gas turbine and a compressor. Such a design differs radically from the usually accepted boiler usage and becomes of the nature of an engine.

Out of these experiments there has been developed the "Velox" steam generator. Two types have been designed, each using a different method of combustion; in one the mixture of air and fuel is exploded cyclically in a series of closed combustion chambers, in the other it is burned under constant pressure. Experiments carried out on the only explosion-type Velox so far built, fully justify the anticipation of extremely high efficiencies, but the design has certain constructional complications, such as valve gear and sparking plugs, which require further development before the machine can be considered as a marketable commercial unit. The constant-pressure-type Velox, on the other hand, is now fully established as a reliable and efficient commercial machine, of which sufficient operating experience is available (in sizes between 25,000 and 70,000 lb. of steam per hour), to justify the claims of high space efficiency, reliability and high operating efficiency. Units for outputs up to 120,000 lb. per hour are in course of construction. Up to the present the designs only allow for the use of liquid or gaseous fuels, but experiments with pulverised coal and mixed fuels are in progress. The experiments with powdered lignite, which is so largely used on the Continent, hold out every promise of success. Co-jointly with those experiments the method of using pulverised bituminous coal is being investigated. The combustion under pressure of this fuel is not likely to present any difficulties, but prolonged operating experience is necessary to ascertain the effects of the ash in the flue gases on the tubes, nozzles and rotating parts of the gas turbine.

Considerable information on the Velox steam generator is given in a paper by Mr. M. G. S. Swallow, M.I.E.E., presented before the North Western Branch of the Institution of Mechanical Engineers recently, a limited number of copies of which are available from Richardson Westgarth-Brown Boveri Ltd., Hartlepool Engine Works, Hartlepool. The paper shows both the constructional and design features of the Velox, also the results of tests carried out on some of the plants which have already been installed, and is of outstanding interest to power engineers.

Fire-Refining Copper at Prescot

Although the decline of the British copper industry, which at one time was of considerable was, primarily due to the exhaustion of native ores, there has always been a desire to revive this industry, and an agreement entered into has enabled a plant to be erected for refining blister copper from one of the Rhodesian copper mines. In this article reference is made to the plant and its operations.

COPPER, in common with other industrial minerals, has a wide variety of uses, but in its primary application it provides the highway over which man sends his messages, communicates with his distant neighbours and transmits the power to turn the wheels of industry and transportation. Together, copper and iron, the one because of its high electrical conductivity, the other because of its magnetic properties, enable man to harness electricity cheaply, efficiently and in diverse manners to his service. Exceeded in production only by iron, copper is relatively cheap and abundant. The major ore bodies of copper are far removed from the world's industrial centres where the metal is consumed. Probably the largest deposits are in the Rocky Mountains and other almost inaccessible districts in Chile, Peru, Mexico and Alaska. Ore bodies of large proportion have recently been discovered in the Katanga mineral distiict of south-western Congo, Africa, Canada, and in Rhodesia. Other deposits are found in Spain, Portugal, Japan, Germany, Russia and Australia.

Ores raised in Great Britain.

At one time considerable quantities of copper ore were raised in Great Britain. Thus, between 1850 and 1860, the amount of copper ore raised in Cornwall averaged 165,900 tons per annum. Practically the whole of this was smelted in the Swansea area, where there were 17 large smelting establishments, and these, with one at St. Helens, constituted the copper works of Great Britain. The art of fire-refining copper was practised in South Wales at that time. Between 1864 and 1890 the production of copper from native ores in Great Britain fell from 13,300 tons to 936 tons.

The decline of the British copper industry was due primarily to the exhaustion of the native ores, and the consequent necessity of importing ores from countries which subsequently established their own smelters. Furthermore, the growing demand for high-conductivity copper for the electrical industries could only be met by the product of the electrolytic refining process. The development of this process was materially assisted by the low cost at which electricity could be generated in the United States of America, and also by the fact that its employment enabled the use of ores yielding valuable by-products—*e.g.*, gold and silver—in the anode mud.

New Refining Plant.

In 1930, however, the drillings of certain Rhodesian copper deposits proved the occurrence of a large ore body, carrying chalcocite of a very high purity and very low in precious metals. During the ensuing year exhaustive tests on blister produced from this source proved it amenable to fire refining for the production of high-conductivity copper, and the results so obtained led ultimately to the return to this country of fire-refining on a modern scale. Early in 1932, the directors of British Insulated Cables, Ltd., decided to avail themselves of American experience in copper refining, as is proved by the erection of a refinery at Prescot. The designing of the plant was commenced in May of that year, and simultaneously a company was formed under the name of British Copper Refiners, Ltd., to conduct the business of the new refinery.

The plant was erected, and has now been operating on a production basis over a year. This refinery was recently the subject of a paper before the Midland Metallurgical Societies by Mr. D. W. Aldridge, in which he stated that the main block of buildings consists of five bays lying adjacent to one another, and so arranged as to provide for the routing of material from the blister storage bay on the north through the charging, furnace and casting bays, to the inspection and shipping bay on the south. Provision has been made at the west end of these buildings for extensions as and when required, and an interesting feature of the layout is that no directional alteration in the flow of work would be entailed by the condition of one or more furnaces with their auxiliary equipment. It is noteworthy that work has already been commenced on the duplication of the greater portion of the original plant.

The furnace bay is 100 ft. long by 18 ft. wide. On a platform immediately above the furnace is installed a waste-heat boiler, while at the east end of the bay is a lean-to building housing two feed-water pumps and also two pumps for supplying water under pressure to the hydraulic plant. The furnace is built on ribbed cast-iron plates, 2 in. in thickness and spaced 1 in. apart to allow for expansion. These plates are supported on re-inforced concrete piers which stand approximately 4 ft. high on a concrete foundation raft, and are capped with ¼-in. steel plates to minimise frictional stresses set up during expansion and contraction of the furnace structure. The concrete raft lies 5 ft. 6 in. below the floor level of the charging aisle, and is bounded by concrete walls which are built away from the furnace steelwork. The areas thus formed at the sides and ends of the furnace, and which are plated over at floor level, permit of the circulation of sufficient air around and between the supporting piers to ensure ample cooling of the bottom. The furnace side plates, which extend to about 6 in. above the metal line, are of 1 in. thick steel stiffened with horizontal joists; they are supported by vertical buckstays, built up of heavy section " I " beams, and tied top and bottom with circular section rods. The latter are spring-loaded at one end, this device eliminating a considerable amount of the adjustment which would otherwise be necessary during the heating up and cooling of the furnace.

The bottom of the furnace consists of a bed of concrete adjacent to the bottom plates, laid as dry as possible, and shaped to receive an inverted arch formed of two courses of 12 in. silica brick. Separating the concrete from the silica is a layer of 16-s.w.g. mild steel sheets, the object being to prevent absorption of moisture by the silica during the period of construction, and to facilitate, at a later stage, movement between the refractories and the concrete. The first course of silica was laid dry and keyed along the sides, after which finely-pulverised silica sand was heated, spread over the surface and worked into any cavities existing at the joints. The second course was then laid on a layer of sand about half an inch thick, but was stopped off at the footing of the side and nose walls, under which magnesite bricks were substituted for silica and separated from the latter by a row of chrome splits. The second course was keyed and treated with silica sand in a similar manner to the first. The side walls to the top of the side plates were built of magnesite bricks with a backing of fire-clay, while in the case of the nose walls magnesite was carried through to the hood; the bridge wall was also constructed of magnesite. A high-

grade of fire-clay brick was used for the back wall and for the firebox walls, while on the front or charging side of the furnace, water-cooled copper blocks, cast with deep flanges to receive fire-brick panels, were installed on either flank and between the charging doors. The furnace dimensions at the metal line, which is 24 in. above the centre of the hearth, are 33 ft. from bridge wall to skimming bay, and 13 ft. between side walls. The roof is of arch formation, and is constructed in three sections. The portion over the firebox which is sprung from air-cooled cast-iron skewbacks, is built of 15 in. fire-clay brick, and makes a straight line joint with the second or main portion, which is of 15 in. silica brick laid dry, and sprung from water-cooled skewbacks. In both cases the bricks are laid in longitudinal rows with broken joints. The third portion or hood is sprung from air-cooled skewbacks, and is built of 15 in. silica bull-head brick laid dry and in rings. An expansion joint of about 4 in. was left between the hood and main portion of the roof. The verb arch, which carries the rear wall of the uptake, is of chrome blocks.

The three charging doors are operated by hydraulic cylinders. The one nearest the firebox is water-cooled, and is constructed of welded steel plates, being lined on the inner face with a 6-in. thickness of fire-clay brick, whereas the remaining two consist of steel frames carrying 6-in. brick panels. These doors are so constructed as to permit of their removal for replacement by means of the charging crane.

Cooling water from the reservoir is circulated through the skewbacks, and also through the bridge door, the various sections being fed from individual pipes connected to a manifold adjacent to the firing end of the furnace. The feed-pipes are all equipped with valves, and the open ends of the return pipes, which discharge into a tundish, are arranged immediately behind these valves, a system of sight-feed and easy regulation being thus provided.

The tap-hole is located on the side of the furnace remote from the charging aisle, and consists of a slot about 6 in. wide extending from the top of the side plates to a point level with the centre of the inverted arch forming the bottom of the furnace.

The furnace is fired with pulverised coal, and in the early stages of operation a number of grades were tried out before one was found which, from all points of view, proved to be well suited to the particular requirements. The essentials are, of course, a clean coal, low in sulphur and ash, high in volatiles, and having a high calorific value. The grade at present in use is a washed slack gauging approximately 99% through half an inch down to a maximum of 5% through $\frac{1}{16}$ in. The sulphur content varies slightly either side of 1%, the ash from $3\frac{1}{2}$% to $4\frac{1}{2}$%, volatile matter from 30% to 33%, and the average calorific value is 14,CC0 B.T.U.s.

The pulveriser is a ball mill of the wind-swept type, carrying a charge of approximately nine tons of balls, and having a rated capacity of five tons per hour. The interior of the mill is under direct suction from an exhauster fan, which induces a current of air sufficient to withdraw the coal which has been reduced to the requisite fineness by the grinding action of the balls. Immediately after leaving the mill, this coal-laden air passes through a selector, and is then delivered to a cyclone separator, where the dust settles out, the clean air being returned to the feed end of the mill. The function of the selector, or classifier, is to reject any oversize coal which may have been extracted from the mill, and this is achieved by subjecting the current of air to frequent changes in direction, and at the same time materially reducing its velocity. The oversize particles drop to the base of the selector, being returned, by means of spiral flights, to the body of the mill for re-grinding.

The coal dust which is separated from the air current by the cyclone falls to the coned portion at the bottom of the casing, and from there is fed through an electrically-driven air lock to an elevator, again of the bucketless type, which in turn feeds an overhead conveyer. This conveyer discharges through two outlets to a 20-ton storage bin, located above the boiler platform at the firing end of the furnace. This bin is equipped with high- and low-level indicators connected with signal lamps on the main switch panel. The coal is ground to pass at least 85% through 200 mesh, and samples are taken at regular intervals for control purposes.

The gases from the furnace pass through the uptake into a Dutch oven, and thence to the waste-heat boiler. The front of the oven consists of a fire-brick-lined door which may be quickly removed to enable a refractory cover to be entered and placed over the uptake. In case of emergency, the boiler may thus be isolated from the furnace.

Casting.

The casting bay is 100 ft. in length, 60 ft. wide, and is provided with two overhead travelling cranes, each of 10 tons capacity. The greater portion of the floor of this section is sunk to a depth of 4 ft. 6 in., and forms the casting pit which is separated from the furnace pit by a reinforced concrete wall. A casting wheel of the Walker type is installed in this pit, the centre of the wheel being immediately opposite the furnace tap-hole. The wheel structure comprises a heavy circular bedplate, having on its upper face a machined track to accommodate radially-tapered rollers which carry the main cylindrical casting forming the hub of the wheel. The hub is approximately 13 ft. in diameter, and is free to revolve around a vertical pillar or spindle projecting from the centre of the bedplate.

The wheel, when in motion, must be virtually free from vibration or lurching, and any required variation in speed must be obtainable smoothly, and with a uniform rate of acceleration and deceleration. To meet these requirements the drive from an electric motor is transmitted through a variable speed reversible oil gear and enclosed reduction gearing to a slow speed pinion which engages with a rack secured to the inner face of the hub casting. This arrangement provides for smooth motion of the wheel in a forward or reverse direction, at any desired speed up to a maximum of one revolution in three minutes.

Moulds are carried on cantilever arms disposed radially around and hung from the vertical wall of the hub, and at the outer ends of these arms provision is made for the housing of levelling blocks to receive the trunnions which are cast on the ends of the moulds. These blocks are on a circle 26 ft. 10 in. in diameter. Normally 13 moulds are carried around the periphery of the wheel, but this number is, of course, subject to variation according to the size of the mould in use.

The pouring ladle has a capacity of approximately 1,000 lb., is suspended on forward trunnions, and tilting motion is effected through a vertical lift-bar, the lower end of which engages with a hook at the back of the ladle, the upper end being attached to a wire rope passing over a guide pulley to the drum of a reversible winding gear. To-and-fro movement of the ladle in a horizontal plane is achieved by means of a bale, carried on the trunnions and coupled to a foot pedal; lateral tilting motion is obtained through a linkage system manipulated by a hand lever.

During the taking out of the charge a considerable volume of water is required for the conveyer bosh and for various cooling sprays, in addition to the normal continuous requirements for the furnace skewbacks. Throughout the casting period, the whole of these requirements are delivered by one of two electrically-driven centrifugal pumps, each having a capacity of 2,500 galls. per min. aganst a 100-ft. head.

Transporting Blister Copper.

The blister copper refined is shipped from the Roan Antelope mines in the form of pigs weighing about three cwt. each, and is transported from the Liverpool Docks to Prescot by road or rail. The pigs are stacked on end in two rows laying adjacent to one another and longitudinally along the decks of the wagons. On arrival, the

raw material is transferred by means of the overhead crane to charging cars for weighing.

After weighing, the blister is passed to storage, the pigs being stacked under their appropriate lot numbers. A proportion of each lot is, however, sampled prior to stacking, and usually every fifth car is switched to the drill room for this purpose. Stacking is carried out in such a manner as to preserve intact each batch of 10 pigs, and thus reloading the cars for charging into the furnace is greatly facilitated.

The daily charge is usually about 150 tons and, in addition to blister copper, includes 10 to 15 tons of scrap-wire in baled form, and 15 to 20 tons of furnace returns such as discarded moulds, ladle skulls and rejected products. The cars are loaded during the morning, the train being shunted to a position just outside the east entrance to the charging aisle, so that it is available immediately after the previous charge is out of the furnace.

Refining Operations.

The period usually elapsing between the commencement of charging and the closing of the furnace is 2½ hours.

At first stage of the melting period the burners are adjusted to give a clear cutting flame, coal being fed at the maximum rate compatible with efficient combustion in the furnace. This condition may be determined by observations at the foot of the uptake, where the gases viewed through the sight hole in the skim door, should be practically clear, or at the stack, from the top of which virtually no smoke should be emitted. As the charge rapidly absorbs more heat, the coal feed may be increased until the maximum firing conditions are reached, and these are held throughout the melting period.

Normally, after five or six hours' firing, the second or flat stage is reached; this is when the portion of the charge still remaining in the solid state is totally submerged in the molten portion. At this juncture the first slag removal is effected. Prior to skimming, the burners are slightly checked, the skim door is opened, the bay trimmed, and the skim bar placed in position. Simultaneously with the commencement of skimming, a blow-pipe is inserted through the port in the bridge door, and is so manipulated as to move the accumulation of slag towards the nose of the furnace. This movement is followed up by subsequent insertions of the pipe through the ports of the middle and front doors in turn, and finally through the latter a long pole may be used to move the slag within reach of the skimmer's rabble.

After completion of the skimming operation the ports in the charging doors are again made up, and heavy firing is resumed. During the second stage of the melting period, the charge is referred to as "coming off bottom," that is, becoming molten throughout. This period is characterised by a general bubbling or boiling of the copper due to the liberation of gases from the yet unmelted portion of the charge. During the later stages, pieces of unmelted metal rise and sink, and finally the coke from the previous charge works loose and carries with it to the surface a considerable quantity of slag, which is removed at intervals in the manner already described. The complete cessation of bubbling, and of coke coming to the surface, is a good indication that the charge is "off bottom." It is a safeguard, however, to open the door ports, and to burn one bite of a fairly heavy pole in the furnace; this serves to agitate the bath and shake afloat any slag or metal still remaining unmelted. The utmost care must, of course, be taken to ensure that the charge is completely afloat before proceeding, and when this condition has been attained, the surface of the bath is skimmed as clean as is practicable, in order to expose the metal to the oxidising and scorifying reactions to follow.

The second or melting period of the cycle is now complete, having occupied a total of eight or nine hours, and the third, or "flapping," period is commenced. Its object is to saturate the bath with cuprous oxide, during which process the minute amounts of remaining impurities are oxidised and slagged or volatilised.

The burners are adjusted to maintain the correct temperature, and the speed of the fan is increased to pull in sufficient air to ensure a strongly-oxidising furnace atmosphere. Two or three pipes are inserted through the ports of both the middle and front doors, and air, at a pressure of about 18 lb. per sq. in., is thus blown into the body of the metal. In order to minimise the splashing of the copper, and so prevent undue fluxing of the brick-work, the open ends of the pipes are submerged as nearly as possible midway between the side walls.

The progress of the charge during the oxidation period is determined by the examination of buttons taken with a "say ladle" having a bowl about 1½ in. in diameter. During the early stages of flapping, the "set" of the copper button is indicative of the condition of the metal. The first button, taken at the commencement of flapping, usually shows an exudation or "worm" associated with the liberation of gases, primarily those of sulphur. As the oxidation and removal of the impurities proceed, the button will shew in turn flat surface, depressed surface, and then a shrinkage cavity extending to the set, which is known as the "nigger." The further progress of oxidation is revealed by the change in the granular structure of succeeding buttons, and these are broken in half to enable the desired observations to be made. The presence of a "big block" structure over the face of a fracture indicates the attainment of the required oxygen content, and subject to this being confirmed by microscopical examination, flapping is discontinued, air pipes are withdrawn and the door ports are closed.

Throughout the oxidation period, just as during the later stages of melting, the accumulation of slag is removed at fairly frequent intervals. During the last two or three skims, clay screenings are thrown on to the metal, the object being to chill and thicken the slag, which at this juncture is of a very fluid nature, and so facilitate the skimming operation. After the final skimming, which is so arranged that its completion coincides as closely as possible with the attainment of "big block," the skim bay is built up with bars, and clay well tamped into position, to make provision for the higher level of metal consequent upon the inclusion of the hot charge, and resulting from surges during poling.

A period of from one to one-and-a-half hours usually elapses before the first button is taken. In the early stages a shrinkage cavity appears on final solidification of the metal; as the poling operation proceeds, this cavity decreases in size and finally disappears. At this juncture block castings are substituted, and the cavity will again appear temporarily, due to the greater size of the casting, and consequently the greater amount of shrinkage. The metal is tapped from the furnace when the block shows a full crown set, and this is usually obtained after about three to three-and-a-half hours' poling.

Characteristics of B.C.R. Copper.

The blister copper as received has a copper content ranging from 99·0% to 99·3%; the balance is made up mainly of oxygen, with smaller amounts of sulphur and iron. Other elements are present in amounts varying from the merest trace up to 0·004%.

These impurities have remained extraordinarily consistent throughout the period of operation, the only variation of any note being the steady decrease in the bismuth content from 0·005% to a current value of less than 0·0025%.

As a point of interest, it may be noted that the average conductivity over productions to date is 100·67% of the International Standard for Annealed Copper. Only in a single instance has the value fallen as low as 100·2%, and this latter figure still shows an ample margin above the A.S.T.M. requirements of 99·3% for electrolytic wire-bars.

Reviews of Current Literature.

Foundry Practice.

DESPITE the progress in foundry practice towards systematic and scientific control, much of pure empiricism remains, and will continue to remain, because in many respects the work in the foundry is an art rather than a science. It is true, of course, that the foundry has become mechanised to an appreciable extent during the last twenty years or so, and the materials used in the making of moulds and of castings are controlled to a greater extent than formerly was considered possible, but in the facilities afforded for accuracy and control of its products the foundry is very far behind the majority of other factories and workshops. Mechanisation certainly plays an important part in some foundries, especially those dealing with standardised products, and to the extent that machinery can be employed, so is it possible to operate on the basis of systematic and scientific control, but there are so many variables to be considered in the making of castings that each different casting must have separate consideration. Particularly is this true as the size of the casting increases and its design becomes more complicated. Yet the authors of this book state in the preface that foundry practice has experienced, in the last few years, a fundamental transformation, changing from a basis of crude empiricism to one of scientific and systematic control.

It is not intended to cast any reflection on this book, which is a very valuable contribution to foundry literature, but to point out that some foundries, dealing with smaller castings of a standardised design, lend themselves to the application of scientific and systematic control, while others, in which both dry sand and loam moulds must be employed, are not so readily adapted to such methods. Actually the majority of foundries still depend upon the individual skill of the moulder. It is rarely indeed that only one method can be adopted in the making of a mould for a casting, and when a large number of similar castings is required the method used may be, and frequently is, selected by trial; with increasing size this method is costly, yet sometimes there is no other alternative. The question of whether a mould should be made in green sand, dry sand, or loam is one not easily decided on scientific lines; certainly there are few foundries in which loam moulding is carried out under scientific control.

Foundry practice is so complex, and the operations so varied, that no single book on the subject is likely to be written which embraces all its complexities. Many books have the weakness of stressing some sections of foundry practice, and almost, if not wholly, excluding other important sections; in this book, however, a foundry superintendent and a metallurgist collaborate and deal with the principles and practice of the foundry, covering the various sections admirably, with the noteworthy exception that the operation of cleaning the resultant castings is omitted; apart from this, however, the authors have made remarkably good use of the space at their disposal. The examples of different types of moulding are well selected and considered, while the chapters dealing with moulding sands, the metallurgy of cast iron and the melting of cast iron are most interesting and informative. In the latter, useful cupola and rotary furnace data is given, while in the chapter on the metallurgy of cast iron the data on foundry mixtures is exceedingly well presented. Although containing only 267 pages—too few for such a comprehensive subject—the authors have evidently endeavoured to make the best use of that available, and have succeeded in presenting, concisely, valuable information that will prove useful not only to the student, but to the journeyman moulder, the foundry executive, the technical director and the metallurgist. In addition the foundry instructor will find the information and method of presentation of considerable help in directing studies on the subject.

The book is well printed and illustrated, and altogether is an admirable addition to the technical literature on the work in the foundry. With the need for foundry education, stressed so much during recent years, and some progress in this direction having been achieved, this book should find many interested readers.

By T. LAING, A.M.I., Brit.F., and R. T. ROLFE, F.I.C. Published by Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C. 2. Price 15s. net.

German-English Metallurgical Dictionary Part 1.

THE infinite difficulty of mastering two languages with that degree of perfection which dictionary-making requires is best appreciated by those who have endeavoured to sound the depths of a foreign speech in its native home: this is particularly true when translating the proper meaning of technical language. It is well known, of course, that technical language has a tendency to play havoc with the literary language. German grammarians and purists, in particular, are up in arms against the lingo of German trade, which they characterise as unpatriotic, puerile, and impossible, but it is inevitable that all technical languages should approximate to a universal language.

In this dictionary the compiler has produced a really useful—that is to say, a clearly arranged, complete and reliable—book, which cannot fail to help the translator to a clearer understanding of the matter which he is translating. Considering the many differences in opinion that exist amongst authorities themselves with regard to technical data the information given is distinctly helpful in arriving at the proper translation. It covers the metallurgy of ferrous and non-ferrous metals and alloys, embracing the various sections from the raw materials—ores, fuels and refractories—to the production and fabrication of the finished and semi-finished products. The words and phrases are arranged alphabetically, but, no doubt owing to lack of space, no attempt has been made to indicate pronunciation; nevertheless this is an excellent dictionary and the metallurgist, in particular, will find it an invaluable guide in the translation of technical data; besides the metallurgist, however, the comprehensiveness of this dictionary makes it an ideal work of reference to all who are intimately concerned with the manufacture and fabrication of metals. It contains 327 pages and numerous conversion tables.

Compiled by HENRY FREEMAN, published by OTTO SPAMER VERLAG, G.m.b.H., Leipzig C5, Crusiusstr, 10. Price RM. 25 net.

Engineers' Purchasing Guide.

THIS is an entirely new engineers' purchasing reference book that Messrs. Hutchinson and Co. (Publishers), Ltd., are preparing for publication in the autumn. It is being compiled by S. Vernon, Wh.Exh., A.M.I.Mech.E., with the assistance of a committee of consulting engineers, manufacturers and engineering associations. I. P. Shirshov, A.M.I.E.E., consulting engineer, is taking a leading part on the editing committee, the manufacturers' section being represented by a number of the principal manufacturers of engineering plant and equipment

In its principal section, this book will deal with a wide range of selected items of plant and equipment used in contracting, factory, industrial, power plant, transport, mining, and metallurgical engineering, the general scheme for considering each item being as follows: a practical definition; condensed specification details; enquiry data and questionnaire, *i.e.*, the essential data that should be stated in an enquiry to enable a supplier to quote, and the essential questions the buyer should ask so that he can receive with a tender sufficient information to enable him to judge the suitability of what is being offered.

Designed primarily as a reference book for buyers, it should be equally useful to the seller by making contact easier between buyer and seller, by eliminating delays, and by avoiding misunderstandings and unnecessary expense in dealing with enquiries.

Thermal and Electrical Conductivities of Metals and Alloys

By J. W. Donaldson, D.Sc.

Considerable work has been carried out during recent years on the thermal and electrical properties, both of ferrous and non-ferrous alloys, with the object of providing accurate data and so to facilitate the development and improvement of various types of machines, and in this article some of this work is reviewed.

THE work which has been done during recent years in determining the physical properties of metals and their alloys, has resulted from the demand made by various classes of workers for more accurate physical data. Scientific investigators, carrying out researches on chemical and metallurgical problems, have been handicapped by the lack of such information, and the same applies to the users of metals such as engineers, where data of such a nature are of great importance in designing and in the development and improvement of various types and classes of machinery. The physical constants required vary, but considerable work has been done on the thermal and electrical properties, both of ferrous and non-ferrous alloys. In an article which appeared in METALLURGIA some four years ago, the author reviewed the work done on thermal conductivity, and it is now proposed to consider the further work done since then, not only on the thermal, but also on the electrical conductivity, as there appears to be an important relationship between those two properties.

Thermal and Electrical Conductivity.

The relationship between thermal and the electrical conductivity has been known for some considerable time. In 1853, Wiedemann and Franz stated that the ratio of thermal to electrical conductivity was the same for all metals, and in 1872, Lorenz, as the result of experiments and from theoretical considerations, formed the opinion that this ratio was proportional to the absolute temperature. He enunciated a law which, when expressed mathematically, states that—

$$\frac{K}{\lambda . T} = \text{constant}$$

where K is the thermal conductivity, λ the electrical conductivity, and T the absolute temperature. This law is also sometimes stated as :—

$$K\sigma = T \text{ constant}$$

where σ is the electrical resistivity.

Drude and Lorenz formed similar conclusions on the development of the electron theory, and the practical experiments of Jaeger and Dresselhorst on aluminium, copper, lead, nickel, and zinc, over the range 18° to 100° C., and the later experiments of Lee and of Meissner showed that for pure metals between—100° C. and + 100° C., the same value is obtained with a slightly decreasing value as the temperature falls to—100° C. Below this temperature the value falls rapidly and varies widely for different metals. For temperatures over 100° C., a series of measurements were made by Schofield ([1]) on aluminium, copper, magnesium, nickel, and zinc of the highest purity obtainable commercially at temperatures up to 700° C. It was shown by these experiments that the values of the Lorenz function for copper, magnesium, and zinc were practically constant at all temperatures, while aluminium showed a rise with increasing temperature, and nickel showed a rise to 300° C. above which temperature it remained nearly constant except for an abnormal value at 400° C. The values obtained were all in good agreement with those of previous observers. It may therefore be assumed that the Lorenz law holds approximately for commercially pure metals.

The work which has been done recently has been undertaken to prove or disprove whether the law holds for alloys. Before considering such work the advantage to be obtained, if such a law is applicable to all metals and alloys, might be pointed out. Thermal conductivity determinations are somewhat difficult to measure experimentally. This is due to the time required to set up steady gradients of temperature and to the maximum temperatures at which such determinations can be made. Published values have as a rule been made at temperatures below 600° C., and are usually too low for the problems where such data are required. Electrical conductivity determinations can be made with much less difficulty, and at high temperatures. If it can be shown that the various alloys, ferrous and non-ferrous, obey the Lorenz law from ordinary temperature to their melting point, then the law has a very important practical bearing, as it would be possible to determine the electrical conductivity and from it to deduce the thermal conductivity.

Ferrous Alloys.

A series of measurements were made on the thermal and electrical properties of carbon steels and cast irons by Masumoto.[2] In the case of the steels, empirical formulæ were determined for calculating the effect which carbon, silicon, and manganese had on their thermal conductivity and electrical resistivity. Sixteen cast irons were also tested with carbon contents ranging from 2·41 to 4·63% and silicon contents of 0·12 to 0·54%. These irons were mainly white irons, and the determinations were made in the chill-cast condition and again after annealing at 1,000 to 1,090° C. for varying periods of time. From the results of these measurements, three curves were drawn showing the relationship of thermal and electrical conductivity, and their ratio to carbon concentration. So far as the steels were concerned, the values obtained showed the Lorenz law to hold with a fair degree of accuracy, and the same could be said of the white cast irons. If graphitisation, however, had taken place as the result of the annealing a rapid increase in conductivity, both thermal and electrical, occurred, and their ratio was also increased considerably. Extrapolating the curves gave values for cementite for the thermal conductivity, electrical resistivity, and their product of 0·017 cals. per cm. per sec., 140 microhms per cc. and 2·38. Masumoto's measurements were made at 34° C. and not over a range of temperatures.

Determinations on the thermal and electrical conductivities of three ingot mould irons were published in the Fourth Report of the Heterogeneity Committee to the Iron and Steel Institute.[3] The electrical measurements were made by Pearce and Morgan and the thermal measurements by the author. The two unused irons tested had thermal conductivity values of 0·095 and 0·103, which increased to 0·103 and 0·107 after the moulds had been in use for 65 casts, and the third iron an average value of 0·092. The thermal conductivity measurements were made over a range of temperatures up to 525° C., and were low when compared with the values obtained from grey irons of somewhat similar composition, cast for engineering and other purposes. The falling-off in conductivity was thought to be due to the nature of the irons, which were

1 F. H. Schofield, "Proc. Royal Soc.," 1925, Vol. 107, p. 206.
2 H. Masumoto, "Science Rep. Tokohu Imp. Univ.," 1927, Vol. 16, p. 417.
3 J. G. Pearce, E. Morgan, and J. W. Donaldson, 4th Report Heterogeneity Committe . Iron and Steel Inst., Section VI., Parts 1 and 2, 1932.

less dense and of a more open nature than normal grey iron castings. The increase in the conductivity during the life of the mould was considered to result from the heat-treatment or annealing influence of the molten steel producing graphitisation, with a consequent increase in the heat-conducting property.

The average thermal resistivity values for these three ingot irons after use were respectively 117·0, 113·61, and 129·04 microhms per cc. These values for the different irons, when considered in relation to their composition, showed that increase in total carbon and silicon had a marked influence in increasing the electrical resistivity, and were in agreement with the results of Masumoto[2] and also of Pinsl[4] in this respect. Pinsl found, in his investigations on the electrical properties of cast iron, that the resistivity was 73 to 104 microhms per cc. at ordinary temperature, and increased by 12 to 14 microhms with 1% increase in silicon, and by 10 to 12 microhms with 1% increase in graphite. The values for the product of the thermal conductivity and electrical resistivity of the three ingot mould irons was fairly constant and showed an approximate relationship, although the constant obtained was somewhat higher than that obtained for pure metals and carbon steels.

Thermal conductivity determinations carried out recently by the author[5] indicated the influence which composition and structure had on iron alloys, and also gave values for the thermal conductivities of certain constituents. The results obtained for a wrought iron and five

TABLE I.

THERMAL CONDUCTIVITIES OF WROUGHT IRON AND STEELS (DONALDSON).

Alloy.	Composition.			K.	
	C.	Si.	Mn.	100°	400°
W	Trace.	0·092	0·20	0·175	0·168
C.S.1	0·10	0·001	0·34	0·161	0·152
C.S.2	0·26	0·140	0·61	0·134	0·128
C.S.3	0·44	0·113	0·67	0·129	0·121
C.S.4	0·92	0·177	0·56	0·120	0·115
C.S.5	1·09	0·058	0·46	0·118	0·112

carbon steels at 100° and 400° C. respectively are shown on Table 1. The value for the wrought iron of 0·175 is higher than that generally accepted for ferrite of 0·174, and, as the wrought iron tested contained a fair amount of slag, it is suggested that Benedick's value of 0·187 for pure iron would be a better value for ferrite. The data obtained for the carbon steels, which show a falling-off in conductivity with increasing carbon content, indicate the influence of the carbon on the conductivity in producing different amounts of ferrite, cementite, and pearlite. Calculating the conductivities of the various steel by Masumoto's formula gave values which approximate closely to those actually determined, and indicate not only the influence of carbon, silicon, and manganese, but also the fact that it is possible to predict the thermal conductivity values of steels with fair accuracy without direct experimenting.

Tests carried out on two malleable irons also indicated the influence of structure. A blackheart malleable iron with a structure of ferrite, temper carbon, and a small proportion of pearlite had a thermal conductivity of 0·150 at 100° C.; and a whiteheart malleable iron, with a structure of pearlite temper carbon, and a small proportion of ferrite a value of 0·115 at a similar temperature. Tests on five special cast irons showed the influence of silicon on the thermal conductivity of such alloys in producing a rapid decrease with increasing silicon up to 2% silicon. With over 2% silicon, however, the falling-off in conductivity was reduced considerably, due to the formation of a fine ferrite/graphite structure. When an austenitic structure was produced in cast iron by the addition of 18 to 19% of nickel and 2% of chromium, the thermal conductivity decreased to the low value of 0·07. The influence of phosphorus on the thermal conductivity value of grey cast iron was to produce a decrease, but not so marked as in the case of silicon and manganese.

Carbon and silicon also have an important influence on the electrical resistivity of grey cast iron. This has been shown in recent work by Norbury and Morgan,[6] who made measurements on a series of cast irons, containing 2 to 4% total carbon, and 1 to 8% silicon. These tests indicate that increase in the silicon or total carbon content has an increasingly greater effect, the higher the silicon or total carbon content. Increasing the silicon from 1 to 2% in an iron containing 4% total carbon increases the resistivity by 50 microhms per cc., whereas in the case of pure iron, the increase is only 13·5 microhms.

Non-Ferrous Alloys.

With regard to non-ferrous alloys, a series of measurements of the thermal and electrical conductivities of 18 aluminium alloys were made by Masumoto.[7] It was found that the greater the amount of the metal added to aluminium, the greater the fall in the conductivities. Heat treatment or annealing increased both conductivities, being most marked in the case of large proportions of silicon and least with zinc additions. Quenching generally diminished the conductivities, thereby indicating the solution of the various constituents in the aluminium, and ageing also diminished them. Although there was considerable variation in the values obtained for the thermal conductivity and the electrical resistivity of the various alloys, the product of the two was nearly always constant for all the alloys, and from the data obtained the mean value of the Lorenz coefficient was $5 \cdot 4 \times 10^{-9}$ at 30° C. It was also shown that the smaller the values of the two conductivities the greater was the value of the product, and that the product was also slightly increased with changes due to treatment. This small increase in the value of the product of the thermal conductivity and electrical resistivity was attributed to the fact that in a good conductor, heat is mainly conducted through free electrons and the heat conducted due to atoms is very small, but as the heat conductivity decreases, the latter

TABLE II.

THERMAL AND ELECTRICAL CONDUCTIVITIES OF COPPER ALLOYS (GRIFFITHS AND SCHOFIELD).

Composition.			Thermal Conductivity Cal./cm./sec.	Electrical Resistivity Ohms/cm³ × 10^{-6}	Lorenz Constant × 10^{-9}
Cu.	Sn.	Zn.			
60·7	0·5	38·5	0·203	9·9	5·7
88·0	10·0	2·0	0·126	16·5	5·9

TABLE III.

THERMAL AND ELECTRICAL CONDUCTIVITIES OF ALUMINIUM ALLOYS (GRIFFITHS AND SCHOFIELD).

Composition			Thermal Conductivity Cal./cm./sec.	Electrical Resistivity Ohms/cm³ × 10^{-6}	Lorenz Constant × 10^{-9}
8% Cu	—	—	0·45	4·06	5·18
4% Cu	2 Ni	1·Mg	0·40	4·66	5·28
3% Cu	13 Zn	—	0·35	6·67	5·52

mode of transmission becomes greater; while the electricity is always conducted by the free electrons and is not therefore affected.

Two groups of non-ferrous alloys were investigated for thermal and electrical conductivities by Griffiths and Schofield.[8] The alloys in the first group were those rich in aluminium, with nickel, magnesium, iron, zinc, or silver as second or third constituent, and in the second group alloys

4 H. Pinsl, *Giesserei Zeitung*, 1928, Vol. 25, p. 73.
5 J. W. Donaldson, *Journ. Iron and Steel Inst.*, 1933, Vol. 78, p. 255.
6 A. L. Norbury and E. Morgan, *Journ. Iron and Steel Inst.*, 1932, Vol. 75, p. 331.
7 H. Masumoto, "Science Rep. Tokohu Imp. Univ.," 1925, Vol. 13, p. 229.
8 E. Griffiths and F. H. Schofield, *Journ. Inst. Metals*, 1928, Vol. 39, p. 337.

rich in copper, with tin, zinc, lead, manganese, or aluminium. The thermal conductivities of all the alloys, which were measured over a range of temperature 20° to 250° C. for the bronzes, and 80° to 350° C. for the aluminium alloys, increased with increase in temperature, in contrast to pure metals, which show little variation with temperature and to ferrous alloys, which show a decrease as the temperature increases.

Seven copper and twenty-two aluminium alloys were tested. The thermal conductivities, electrical resistivities, and the Lorenz constant for two of the former, and three of the latter are given in Tables 2 and 3 respectively. These values are typical of the two groups and show that the thermal values for aluminium alloys are approximately 70 to 80% that of pure aluminium, and 10 to 20% of copper for the bronzes.

The ratio of thermal to electrical conductivity in the range 80° to 300° C. for these alloys obeys the Lorenz law with one or two exceptions. In the case of the aluminium alloys an average value of $5{\cdot}5 \times 10^{-9}$ was obtained, and this approximates to the values obtained for the pure metals, which form the principal constituents of the alloys. In the case of the copper alloys, the average value was slightly higher, being $5{\cdot}9 \times 10^{-9}$. The Lorenz values obtained for each alloy showed little variation with temperature.

A series of thermal conductivity measurements were also made by Hanson and Rogers[9] on aluminium alloys containing from 0·18 to 30% copper, and on copper alloys containing 1·75 to 12·8% aluminium, and also on copper with small amounts of either iron, nickel, arsenic, or phosphorus. The measurements were made over a range of temperature of 60° to 270° C. and the aluminium-copper alloys and the copper-iron alloys were tested as cast and after heat treatment. In the aluminium-copper series of alloys the thermal conductivity decreased from 0·513 for pure aluminium to 0·346 with 20% copper, and the cast alloys had a lower conductivity than the alloys annealed at 500° C., probably due to the retention of a larger amount of copper in solution. Additions of aluminium, arsenic, nickel, iron, and phosphorus all produced a marked reduction in the heat-conducting property of copper; aluminium, arsenic, and phosphorus exerting a greater influence than nickel or iron. It is also noted that the effect of iron is influenced by the thermal treatment to which the alloys were subjected, alloys quenched from 600° C. in water having higher values than alloys quenched from 1,000° C. This difference is stated to be due to the retention of a greater amount of iron in solution when they are quenched from the higher temperature.

9 D. Hanson and C. E. Rodgers, *Journ. Inst. Metals*, 1932, Vol. 48, p. 37.

Conclusions.

In general, measurements made of the thermal and electrical conductivities of metals and alloys show that Lorenz law holds for pure metals. For alloys such as steel and the alloys of copper and of aluminium, it also holds with a considerable degree of accuracy, but the same cannot be said of cast iron. With grey cast iron, there are indications of a possible relationship between the two properties, but due to the complex nature of this alloy a relationship is very difficult to establish.

The Utilisation of Coke Oven Gas

From economic and operating standpoints, the conditions involved in the utilisation of coke oven gas varies with different plants, but much greater attention is now being given to the economies effected by making fuller use of this gas. The subject was discussed by Major M. Koopman (late R. E.) in a paper presented at a recent meeting of the Institute of Fuel, extracts of which are given in this article, in which the possibilities of a gas grid in several areas in England are considered.

THE importance of making fuller use of coke oven gas has certainly been under-estimated in the past, and is probably not appreciated by most people even now, although the subject has been stressed both in this country and abroad. Although there has been a marked revival in the iron and steel industry, the need for reorganisation is even more pressing than formerly, and schemes must be put into operation with a minimum of delay, if the British iron and steel industry is to take full advantage of improved trade conditions when they return.

It is fully realised that to materialise the utilisation of coke oven gas would involve a considerable expenditure of capital, and in view of that, it is important to recognise quite clearly, before going into details, that no speculative experiment is being advocated, but a course of action whose ultimate success would be practically guaranteed. The grounds for such a claim lie in the extensive systems which have grown up on the Continent—in Belgium, Germany, France and Holland—for distributing coke oven gas to industrial and domestic consumers. The Belgian gas grid, for example, has nearly 160 miles of pipe line, and is selling 85 million cub. ft. of coke oven gas per mile of main per annum, whilst in the Ruhr there are about 600 miles of pipe line, with an annual sale of nearly 50 million cub. ft. per mile of main.

The economic success of a gas grid will depend upon as large a quantity of gas as possible becoming available for distribution: that is to say, that as large a proportion as possible of the coke oven gas produced must be a surplus. Thus, waste heat ovens are quite unsuitable for this purpose, as the surplus available, after demands for heating the ovens have been met, is small. In regenerative ovens, on the other hand, 50 per cent., or more, of the gas produced is surplus, and this is the chief reason why waste heat batteries are now regarded as obsolescent. The particular development which gave the greatest impetus to the Ruhr gas scheme, however, was the construction of a regenerative battery of coke ovens in Mülheim, in 1910, heated with blast-furnace gas. This is technically possible because the temperatures required in coke ovens are considerably lower than those occurring in most other industrial furnaces, and a relatively poor fuel, such as blast-furnace gas, having a calorific value of about 100 B.T.U.'s per cub. ft., may be used instead of the very rich coke oven gas, whose calorific value is over five times as great.

The use of coke oven gas for municipal purposes dates back some time in Germany, for as early as 1905 the Thyssen Waterworks Co. was selling surplus gas from its coke ovens to Mülheim and Hamborn, and the first high-pressure gas line was laid down in the Ruhr district about 1910. The chief developments, however, have been in the post-war years. The old batteries, which were no longer of use as a result of the war and the Ruhr occupation, were scrapped, and in their place large compound and regenerative coking plants of the most up-to-date design were erected on sites carefully selected from economic and technical considerations. This was facilitated by the amalgamation of many important firms in about 1926, and, in general, coke ovens were erected on the sites of the collieries and, where possible, near the large iron and steel works. The two guiding factors are, firstly, that the transport of coke is much cheaper than that of the coal from which it is made, and secondly, that a supply of blast-furnace gas is required for heating the ovens. This latter point is considered of such importance that pipe lines nearly three miles long were laid down in one instance, and boosting plant installed for

transmitting the blast-furnace gas. Where there are no blast furnaces near the collieries, gas producers are installed.

Experience in Germany has shown that, for municipal purposes, coke oven gas can compare favourably with any other of the fuels available. Transmission losses are very low in comparison with high tension electric current, and transport costs are not high, provided that the load does not fluctuate unduly. Moreover, German authorities claim that in recent years it has been found possible to design industrial gas-fired furnaces whose thermal efficiencies approach that of an electric furnace.

In some respects, the Belgian gas grid is more remarkable than that of the Ruhr district, as the quantity of gas distributed per mile of main is considerably greater and a greater proportion of gas is used for municipal and domestic purposes. Gas is supplied to the grid from five coke oven plants, of which it is interesting to note that one was constructed as a gasworks, and not primarily for the production of coke. This particular works is that of the Cokeries du Brabant, at Pont Brûlé, and the others are situated at Tertre, Monceau, Marly, and Hoboken. The network of the grid thus extends most of the way between the French and Dutch frontiers; the main pipe line is 73 miles long, and the total length, including branches, over 160 miles. The full capacity of the system is over 30 million cub. ft. per day. The physical and chemical condition of the gas is kept strictly to an agreed quality, and impurities in the gas are not allowed to exceed certain specified maxima. Infringements of these conditions are compensated by a sliding scale of penalties; and the price of the gas to consumers is fixed by the quantity bought and the current price of coal.

France is another country in which a gas grid has been established in the last few years, around Bethune, Douai, Lille and Valenciennes, as centres, and extending over a large part of the north of France. It is interesting to note that this has been an economic success, despite the fact that the annual consumption of gas per head of population in France is only about one-third of what it is in England.

In France, as in Belgium, there has been a shortage of metallurgical coke, and even now about one-third of the coke quantity used has to be imported. Of the remainder, which is produced in France, about one-half comes from the coke ovens in the north of France. In 1930 before the slump, the consumption of metallurgical coke was 10 million tons, and the production of coke oven gas about 14,000 million cub. ft. as compared with a total output of Town gas of rather more than 5,000 million cub. ft. Actually, the consumption of Town gas was about equal to the production of coke oven gas in the north of France.

If necessary, a much larger surplus of gas could be made available for distribution, as only one coke oven plant (Anzin) is heated with producer gas, although heating by producer gas is customary in gasworks. On the other hand, there has been a tendency for the consumption of coke oven gas in the mines to which the coke ovens are attached to decrease, as it has been found more economical to burn inferior coals under the boilers. The latest figures available show that the quantity of gas distributed annually by the grid is now of the order of 9,000 million cub. ft.

Coke oven gas has been put to a variety of uses in France, and one of the most important developments has been its increased competition with fuel oil, in cases where the latter had ousted Town gas. It has certain technical advantages over fuel oil, notably that it can be regenerated, and also the primary air may be regenerated; whilst when fuel oil is used, it is unsafe to heat the primary air above 200° C., as otherwise the oil may be decomposed before combustion, and coke deposited. It has been found most useful in cases where the material to be heated is only in the furnace for a short time, and rapid heating is therefore essential; and in many such cases considerably increased output has been obtained. Its chief industrial use has been in the metallurgical industry; in forges, for annealing and other heat treatment, and for melting (*e.g.*, bronze); but it has also been used in glass and ceramic works, and even in bakeries. Many towns, notably Metz, draw the bulk of their supply of gas from coke ovens, and in Valenciennes the annual consumption per head of population is 8,000 cub. ft.

The chief district in Great Britain which has a sufficient concentration of coke oven plants to render the formation of a gas grid possible is South Yorkshire, or, more particularly, the Sheffield area. Possibilities in this direction have been carefully considered by experts in the past, and the idea has met with their practically unanimous approval. In fact, the Departmental Committee on Area Gas Supply, in reporting to the Board of Trade in 1930, went so far as to say that the formation of a South Yorkshire gas grid was urgently necessary. Nevertheless, although certain coke oven plants are selling surplus gas to municipal gas undertakings, practically no progress has been made with the scheme for the formation of a grid.

The bulk of the gas distributed by such a grid would have to be consumed by industrial users, chiefly the various iron and steel manufacturers in the district. The advantages of clean Town gas or coke oven gas over other fuels have been fully established in the iron and steel industry, and a supply of gas at an economic price—say 1·5d. to 2d. per therm—would have a ready and assured market. As a matter of fact, the increase in the use of coke oven gas in recent years is clear proof that consumers have found it entirely satisfactory for their needs.

The total quantity of coke oven gas sold in this country in 1932 was about 15,500 million cub. ft.; and it is estimated that the potential consumption in iron and steel works alone in the Sheffield area (assuming that the gas was used for firing open hearth furnaces as well as for other purposes) would be about 23,500 million cub. ft. per annum. Even this figure represents only about one-half of the calorific value of the raw coal which would be replaced by gas. It is clear that to satisfy this demand, and to have surplus gas available for other consumers, some of the older plants in the South Yorkshire area would have to be modernised, although it would probably be unnecessary to alter the location of the existing plants. Under these circumstances, the figure suggested for the maximum possible output is 33,000 million cub. ft. per annum, a figure which compares with the annual distribution of gas through the Ruhr grid.

The scheme proposed by the Area Gas Supply Committee provided for the collection of gas from 19 coke oven plants to a maximum of 80 million cub. ft. per working day. This would involve laying down a network of 73½ miles of mains, and if it were found possible to sell gas outside the Sheffield area, no technical difficulty would be anticipated in installing compressing plants, and making the necessary arrangements for long-distance transmission.

The greatest hindrance to the furtherance of such a scheme would be the statutory restrictions at present in force. These were enacted originally mainly to protect existing gas undertakings, but as the success of the grid scheme would necessitate the co-operation of the existing gas companies, it should be possible for the necessary fresh legislation to be passed without overmuch opposition. For example, at present, new gas undertakings are debarred from transmitting gas across main roads without the consent of existing gas companies; this restriction would have to be removed, and also it would be desirable to give the Minister of Transport statutory powers to grant wayleaves, when necessary, for cross-country transmission, as is already the case for the transmission of electric supply.

Conditions are not really favourable, either in West Yorkshire or in Lancashire, for the setting up of a grid, and the only remaining district which has any possibilities is the Cleveland area. This, again, is an important iron and steel manufacturing district, and iron and steel works would provide the bulk of the gas produced. Conditions in this district are such that the cost per therm of producer gas is considerably lower than that of coal gas, and although a certain amount of coke oven gas could advantageously be used internally in the works, in cases where a high-

grade fuel was desired, most of it would have to be disposed of to outside undertakings. At the present moment most of the gas is wasted, or burnt where an inferior fuel would be good enough, but the supply available would be more than sufficient to meet the potential demand.

It must not be inferred, from what has already been written, that no progress has been made in the internal use of coke oven gas in iron and steel works in this country; on the contrary, co-ordinated schemes of gas economy have been worked out and put into operation in a number of instances. There are several outstanding examples of this, namely: Normanby Park Steelworks at Scunthorpe, Richard Thomas and Co. at Scunthorpe, Thos. Firth and John Brown Ltd. at Sheffield, the Consett Iron Company at Durham, and the United Steel Companies Ltd. (Steel Peech and Tozer Branch, at Templeborough). It is interesting to note, *en passant*, that surplus coke oven gas from the Consett Iron Works is sold to the municipality of Newcastle, but it is proposed here only to give details of the arrangements at Normanby Park and Templeborough. These two are, perhaps, of the greatest interest of all, and are essentially different in that Normanby Park is a compound works, where blast furnaces are in operation and blast-furnace gas is available, whilst Templeborough is a steelworks pure and simple, with no supply of blast-furnace gas.

The introduction of coke oven gas firing has led in almost every case to an increase in thermal efficiency of at least 25%, and in some cases the thermal efficiency has been more than doubled. For instance, continuous re-heating furnaces are attaining thermal efficiencies on the average of 60%, by using high-pressure gas, and being able to control the efficiency of combustion with the greatest amount of accuracy.

The burners used are of the "Selas" type, in which the combustion air is induced into the burner by the gas itself; and it has been found possible to obtain an exact control over the amount of air introduced. This has been well demonstrated by an experimental investigation at the works. The gas pressure was set at 6 lb. per sq. in. and the air screws adjusted to give a furnace atmosphere of analysis 10% CO_2, 0.8%, O_2, and CO nil. Without altering the air screws, the gas pressure was varied between 1.5 and 6 lb. per sq. in., and, throughout the tests, the analysis of the furnace atmosphere was found to remain unchanged.

It seems clear that coke oven gas, provided the price is reasonably low, can be used to replace other fuels—more particularly raw coal—in the manufacture of iron and steel; and also that surplus gas could be sold through a grid to municipal gas undertakings, or to other industrial consumers, to the mutual benefit of coke oven owners and consumers. There are a few combined iron and steel works where gas economy is on a highly organised baiss, and where the maximum possible use is made internally of surplus gas, but even in these cases there still remains a proportion which could be disposed of outside the works.

In the case of coke ovens attached to collieries, and not associated with iron and steel works, it would obviously pay the collieries to dispose of all the gas they possibly can, and also to heat the ovens with producer gas, provided that there is a market for the extra coke oven gas thus released for disposal. Similarly, it would be desirable for coke ovens attached to blast furnaces to be heated by blast-furnace gas.

It is doubtful whether any technical reorganisation of the iron and steel industry will be possible without a simultaneous reorganisation of coke supplies, and the matter is one for the consideration of colliery owners, and especially for collieries to which coke oven plants are attached. A prosperous iron and steel industry means increased prosperity for the coal industry; and in this particular instance it is as well to remember that the maximum rate at which coke can be burnt in the blast furnace hearth, compatible with smooth furnace operation, depends more than anything else on the quality of the coke.

The chief cause of the present unsatisfactory state of affairs is, of course, that too large a proportion of existing coking plants are out of date as regards both capacity and type of installation. In 1929 it was estimated that the average capacity of a coke oven plant was about one-fifth as much in this country as in Germany or America; and it is axiomatic that larger plants are more economical than smaller ones provided that they can be operated at reasonable capacity. Moreover, the size of individual ovens is far too small in the majority of cases. As an example of modern developments, the new Otto ovens at the Consett Works, laid down in 1929, have a weekly output of about 130 tons per oven, which is over four times as great as the average for all by-product coke ovens in this country in operation at that time.

So far as the type of installation is concerned, only regenerative ovens can now be regarded as adequate. In recommending the modernisation of plant it is assumed that full use will be made of surplus gas, and that as much coke oven gas as possible will be released for disposal outside the works. This being the case, waste heat ovens are of no use.

It has already been suggested that there would be no need to alter the sites of many of the existing cokeries in South Yorkshire, provided that the gas grid scheme were put into operation. If, however, it becomes practicable to build new coke oven plants, designed specially to satisfy the needs of the iron and steel industry, the locations of these plants must be chosen with the utmost care. The guiding factor must be cheapness of transport of materials. Blast furnace gas should be used for heating the ovens, and, wherever feasible, as much coke oven gas as possible utilised in the works. It is recommended that, where there are a number of iron and steel works in fairly close proximity, their needs shoud be satisfied by one or two large central cokeries. The success of this would depend on the willingness of the iron and steel works, in the protection of their own interests, to take a fair proportion of coke oven gas. Such large central plants would have the advantage of being able to utilise a wider range of coals than smaller plants, and full advantage could be taken of the researches carried out in recent years on the blending of coking slacks, by the three Coke Research Committees and by other investigators.

In districts like South Yorkshire—and, possibly, Cleveland—where there is a great concentration of coke ovens—the formation of a gas grid seems to be the only satisfactory solution to the problem. It may be noticed that no mention has been made of the utilisation of coke oven gas for purely chemical properties. There may be possibilities of this kind—particularly if new processes are invented in the future—but the whole question is so uncertain that it is safer, in developing a scheme, not to rely upon any outlet for surplus gas existing in this direction. Gas, then, would have to be used exclusively for heating and illumination, and it would actually be to the advantage of municipal gas undertakings to buy coke oven gas from the grid at an economical figure, and redistribute it to their own consumers, through their own system. If there were still a surplus, then long-distance transmission would have to be considered, and the success of the Ruhr grid indicates that this would present no particular difficulty, even allowing for differences in conditions in Germany and England.

The whole question is one which concerns three very important industries—iron and steel, coal, and gas—and the willing and whole-hearted co-operation of all three must be forthcoming. The policy advocated is admittedly a bold one, but, under present conditions, the only ultimate safety lies in boldness; and there is no reason why all three industries should not benefit.

It is a question of national importance, and the author has attempted to express the point of view of that section of the iron and steel industry which he represents, whilst deliberately refraining from avoiding any controversial issues.

Corrosion of Zinc in Chloride Solutions

By C. W. Borgmann and U. R. Evans.

Results of experiments to determine the corrosion of zinc in sea-water and distilled water, and also in potassium solutions of different concentrations, are discussed in this article.

ZINC coverings are largely used for the protection of iron work. Their life varies greatly with the conditions, being often very short in acid atmospheres—a matter easily understood. Failure also occurs prematurely if the zinc becomes wetted with definite drops or patches of salt water—as opposed to fine salt spray. Nevertheless, whilst there has been much work on the corrosion of zinc under conditions of total immersion in chloride solutions and under conditions of salt spray, there has been little quantitative study of the attack under water line conditions. Work under these conditions is described in a paper presented at the recent general meeting of the Electrochemical Society, which includes not only experiments using sea-water and distilled water (two liquids which are particularly destructive to zinc), but a study of the action of potassium chloride solutions of different concentrations. This salt was chosen to bring the results into line with the work of Bengough and his colleagues on fully immersed zinc and iron, and also the work of Evans and Hoar on partially immersed iron.

Actually there are fundamental reasons why the corrosion of zinc under conditions of *partial immersion* possesses special scientific interest, since it might be expected to depend on somewhat different factors from corrosion under conditions of total immersion. The accurate measurements of Bengough, Lee and Wormwell[1] on iron and zinc have shown that, under fully immersed conditions, the rate of attack first increases with concentration, reaches a maximum value and then falls off again, owing to the diminishing solubility of oxygen in concentrated salt solutions. At these high concentrations, the corrosion rate is controlled by the rate of supply of oxygen to the metal; highly purified iron gives nearly the same rate of corrosion as mild steel in 0·1N potassium chloride, but the rate of evolution of hydrogen is less. There is indeed no apparent reason why oxygen should travel down towards steel quicker than to pure iron, but the liberation of hydrogen will be facilitated by certain impurities.

These results, obtained under conditions of "oxygen starvation," stand in contrast with all the data regarding atmospheric attack, where oxygen is in excess; when exposed to the outdoor atmosphere and also when intermittently sprayed indoors, different varieties of iron and steel corrode at very different velocities, although the purest is not always the most resistant.[2] In the tests of the Institute of Civil Engineers, the difference between the best and worst materials was far greater in the aerial tests than in the immersed tests.[3] Schikorr[4] has found a marked difference between the corrosion of pure iron and steel under conditions of oxygen excess. Drops of distilled water placed on the steel surface produced much corrosion, whilst those on the pure iron surface usually produced no attack at all; yet specimens of the two materials, when completely immersed in the distilled water, corroded at approximately the same rate, the velocity being determined by the rate of oxygen supply, not by the nature of the metal.

In studying the corrosion of half-immersed iron and steel, Evans and Hoar[5] found that the maximum corrosion velocity lay between 0·2 and 0·6N for different materials—a far higher value than that found by Bengough (below 0·0001 N) under conditions of total immersion. At low concentrates, the velocity calculated from purely electrical data showed good agreement with that measured directly. At high concentrations, the velocity fell far below the maximum value, being in this range proportional to the oxygen solubility. The diminished velocity was connected with the fact that the cathodic reaction becomes confined to the narrow meniscus zone; for elsewhere, there is insufficient oxygen for cathodic depolarisation, apparently owing to absorption by corrosion products; at the lower levels, absolutely no oxygen could be detected. With half-immersed specimens of zinc, however, far more oxygen was found at the lower levels; the liquid drawn off from the lower part of a vessel in which zinc was corroding was found to contain oxygen to the extent of 19·3% of the saturation value, although analogous experiments on iron showed no oxygen at all at this level. These facts suggest that the curve connecting concentration and corrosion for half-immersed zinc might have a special character. Even in Bengough's total immersion experiments, the maximum corrosion appears at far higher concentrations for zinc (about 0·02 N) than for iron (below 0·0001 N).

It was decided, therefore, to study the concentration-velocity curve of zinc, and also to examine the effect of purity, since on zinc there is a better prospect of escaping the equalising effect of oxygen starvation. Even on iron, it had been found that the partial immersion method showed up differences in the velocity of attack upon different varieties of iron and steel, both in sodium and ammonium chloride solutions.[6] Part of the work on zinc was conducted on plate specimens. But it was felt that the use of roughened specimens (or even smooth specimens with a cut edge) may mask the effect of purity, since physical heterogeneity then remains, even if the metal be chemically uniform; moreover, surface unevenness will reduce any protection due to an oxide film—a protection which is more likely to be attained on homophase than heterophase material.

For this reason, some of the experiments were made on rods of zinc or zinc alloys *cast in glass*, the cast surface being bright and without sharp irregularities; although slight departures from complete smoothness occurred in places on the specimens, these places did not constitute the seats of special attack. Three representative alloying constituents were tested; (i) copper, a homophase impurity, capable of being redeposited during corrosion; (ii) aluminium, a homophase impurity which will not be redeposited, and (iii) iron, a heterophase impurity. Experiments were carried out both with oxygen and air above the liquids, and Bengough's oxygen absorption method, as well as the loss of weight method, was used to follow the attack. Other series of experiments were conducted in distilled water and in sea water. For comparison, some measurements were made on cadmium rods and on electrolytic iron sheet. In all cases, the object was to measure what Brown, Roetheli and Forrest call the "Initial Corrosion-Rate."

1 G. D. Bengough, A. R. Lee and F. Wormwell, Proc. Roy. Soc. (A), 131, 494 (1931); 134, 308 (1931).

2 See, for instance, Proc. Amer. Soc., Test. Mat., Reports of Committee A5, issued annually; also U. R. Evans and S. C. Britton, First Report of the Corrosion Committee of Iron and Steel Inst., p. 139 (1931); W. H. Hatfield and H. T. Shirley, *Ibid.*, p. 156; J. C. Hudson, *Ibid.*, p. 211.

3 J. A. N. Friend, "Deterioration of Structures by Sea Water," 9th Report, p. 9 (1929),

4 G. Schikorr, Z. Elektrochem., 39, 409 (1933).

5 U. R. Evans and T. P. Hoar, Proc. Roy Soc. (A), 137, 343 (1932). Also T. P. Hoar. Dissertation, Cambridge University (1933). Our thanks are due to Dr. Hoar for permission to quote some unpublished data.

6 S. C. Britton and U. R. Evans, Trans. Electrochem. Soc., 61, 450 (1932).

A summary of the results of tests on half-immersed zinc sheet in potassium chloride show an initial corrosion velocity rising steadily with the concentration up to 3 N concentration, whereas on half-immersed iron the velocity falls off at high concentrations ; the difference between the behaviour of the two metals and also the apparent discrepancy with Bengough's results on totally immersed zinc are explained by the fact that on half-immersed sheet zinc oxygen starvation is largely avoided.

Tests on half-immersed zinc rods, cast in glass, show a maximum velocity somewhat below 1·0 N, the rounded shape being less suited for oxygen replenishment than the flat form of the sheet specimens. Rods of very pure zinc are corroded in 0·1 N potassium chloride only slightly more slowly than ordinary pure zinc ; the addition of copper (and probably iron) slightly accelerates whilst that of aluminium appears slightly to retard the initial attack, but the effect of the second constituent is much smaller than in attack by acids. Very little hydrogen is evolved in half-immersed experiments on smooth rods.

No real immunity of zinc sheet towards sea water or distilled water can be obtained by reducing the iron or lead contents, by protecting the edges or by avoiding a roughened surface. The steady velocity of attack on half-immersed zinc is not permanently affected by temporary fluctuation, by vibration or by pre-saturation of the solution with oxygen. The causes of the considerable " scatter " between the results of duplicate experiments are discussed. Where the velocity is controlled by oxygen supply, it will be very sensitive to small changes of temperature and vibration (which may affect the oxygen supply) and comparatively insensitive to the nature of the specimen, whereas when oxygen starvation is eliminated, the reverse will be the case, as has been actually observed.

The Electrochemical Society

Many important subjects were discussed at the recent Spring Convention, and in this article brief reference is made to a few of the papers presented.

MANY important topics of interest were discussed at the fifty-fifth general meeting of the above Society held recently. Amongst the subjects discussed were linings for electric furnaces, high voltage insulators, chemically resistant glass ; while about a dozen reports were presented, dealing with the progress made in various branches of electro-organic chemistry, electro-refining and electroplating. Included in these reports was one on cobalt, another on germanium, and a third on indium. Brief extracts from some of the papers presented are given in the following notes.

Electrochemical Properties of Germanium.

It has been observed that the presence of germanium salts in extremely small quantities in the electrolyte may cause much trouble in the production of electrolytic zinc.[1] Scales or spots appear on the cathodes which rapidly increase in size. If allowed to continue, this action results in resolution of the zinc cathode. According to Tainton, quantities as small as one part of germanium in ten million of solution may produce this marked effect. An investigation by Messrs. J. T. Hall and A. E. Koenig was designed to determine, if possible, the nature of this action through the study of the electrochemistry of germanium, with special reference to zinc sulphate solutions.

As a result of this investigation the authors determined that germanium can be deposited electrolytically from strong aqueous KOH solutions of the dioxide. When coherent coatings of Ge are obtained, the under metal has no effect on the electrochemical behaviour. Ge can be deposited from a molten electrolyte that will dissolve its dioxide. The most consistent potential for the chain, $Hg/Hg_2Cl_2/N\ ZnSO_4/Ge$ is 0·56 volt, in which the normal calomel cell is the more positive when the Ge is electrolytic. The chain potential with massive Ge is lower, being about 0·28 volt. Sulphuric acid lowers the potential of Ge against $NZnSO_4$ and also against a solution of its ions. Wide variance in sulphuric acid concentration has very little effect on the single electrode potential of Ge when Zn and Ge ions are absent. The voltage of the chain, Hg/HgO, NKOH/3NKOH/Cu, at which Ge commences to plate out on Cu from 3NKOH solution of GeO_2, is less than the voltage necessary to liberate hydrogen on Cu under the same conditions, and greater than the voltage required to liberate hydrogen at an electrodeposited germanium surface from the same solution. These facts probably account, in part at least, for the scabbing of Zn cathodes. The hydrogen overvoltage of electrodeposited Ge is about 0·32 volt, that of massive Ge about 0·25 volt. From this it is evident that the hydrogen overvoltage of Ge is not affected as much by a change in the surface of the metal as is the single electrode potential. Ge replaces silver from silver nitrate solution but does not replace Cu, Hg, Sn, As, Sb, or Bi from their chlorides nor Pb from the nitrate.

The Rate of Displacement of Copper from Solutions of its Sulphate by Cadmium and Zinc.

One of the most interesting investigations which have been made of the rate of reduction of metal ions by more active metals is that by Centnerszwer and Heller on the displacement of copper by metallic zinc.[2] These authors conclude that the rate is governed by the diffusion process at low stirring speeds, and by the chemical process at higher

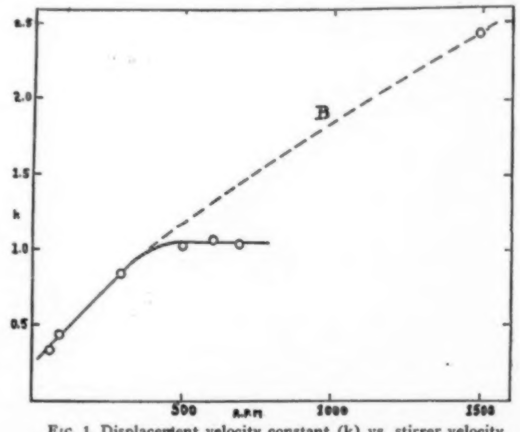


FIG. 1. Displacement velocity constant (k) vs. stirrer velocity (r. p. m.). Displacement of Cu by metal zinc. Centnerszwer and Heller's results with 0.02 molar $CuSO_4$ solution.

stirring speeds where the rate becomes independent of the speed of rotation of the zinc specimen. The displacement rate in such a system is difficult to duplicate with exactness, probably because the metal specimen quickly becomes badly worn and pitted, and copper deposits on it in degrees of sponginess or hardness which depend on the stirring speed, the concentration of copper and other ions, the

1 Tainton, Trans. Am. Electrochem. Soc. 57, 279 (1930).

2 Centnerszwer and Heller, Z. physik. Chem. A161, 113 (1932).

temperature, and other factors. Even though consistent results are obtained in a series of experiments run under similar conditions, it is impossible to define these conditions with exactness, since the active area of the copper deposited and exposed to the solution, the electrical conductivity of the copper and that of the solution in contact with it, and the area, etc., of the zinc, are unknown. Therefore reliance must be placed on the relative displacement rates as some single factor is changed at a time, rather than the absolute rates, for information concerning the rate-controlling mechanism.

In Fig. 1 is replotted the experimental results of Centnerszwer and Heller, including one rate measurement (1,480 r.p.m., $K = 2 \cdot 43$) which they reported but omitted from their plotted curve, probably because of some suspected inaccuracy. It is necessary, however, to decide whether the displacement rate really becomes constant at a value of about $1 \cdot 0$ for the displacement velocity constant (k), or follows a course more like the broken B of Fig. 1. An investigation undertaken to decide this question and to investigate further the importance of the diffusion process to compare the action of cadmium with that of zinc in this system, to compare the solution rates in these systems with those of the similar case of metals dissolving in acids has been carried out by Messrs. C. V. King and M. M. Burger.

As a result of this research the rate of displacement of copper from dilute copper sulphate by cadmium and zinc has been measured and compared with previous experiments and the rate of solution of zinc in acids. The rate is controlled, up to peripheral speeds of the metal surface of at least 44,000 cm/min., by diffusion and electrolytic transport of the Cu ion to the surface of the more active metal and the Cu already deposited. There is no indication that the chemical reaction rate is slow enough to be a controlling factor at any stirring speed studied.

Ductility and Adhesion of Nickel Deposits.

The application of nickel and chromium electrolytic deposits on bases of copper, brass or steel, does not ordinarily require much consideration beyond good adhesion, good appearance, and good corrosion resistance. When these requirements are fulfilled, most, if not all, plated fabricated articles are acceptable. However, when fabrication is desirable subsequent to electroplating, new and interesting plating problems are encountered. Nickel electrodeposits, whether on sheets of steel, tinplate, copper or brass, when plated from the same solutions present similar problems. In the case of Ni plated steel, however, unless use is made of the ferroxyl paper test or microscopic examination of deformed areas, the hardness of the Ni deposit is not always easily detected by the purchaser of pre-finished sheet which is to be fabricated.

After some development work a very ductile type of electrodeposited nickel has been evolved. As a result of an investigation by Mr. F. P. Romanoff it is shown that the ductility of electrodeposited nickel is a function of the crystal structure and of the contained basic salts and gases. Hard fibrous or columnar nickel structures[1] have an apparent hardening effect on a ductile base even when very thin. This apparent hardening of the base disappears upon removing the deposit. Full ductile conical nickel structures of any thickness will not affect the base adversely, Ductile nickel can be hardened by absorption of hydrogen through action as a cathode in alkaline or acid solutions. Chromium deposition on nickel has the same effect. Part of this hardening can be overcome through vacuum or heat treatment, or by chromium plating under conditions which prevent the absorption of too much hydrogen. Testing for adhesion by the Erichsen extruded cap test, or modifications thereof, is shown to be unreliable. A modified cap test is given which will always detect poor adhesion.

[1] Trans. Am. Electrochem. Soc., 44, 397-425 (1923).

The Electrodeposition of Copper, Nickel and Zinc Alloys from Cyanide Solutions.

This paper represents the first part of an investigation by Messrs. C. L. Faust and G. H. Montillon on the co-deposition of copper-nickel-zinc from cyanide solutions. It was undertaken to find those conditions of temperature bath composition and current density that would give deposits of "nickel-silver" colour. The authors show that copper-nickel-zinc may be simultaneously deposited from potassium cyanide solutions of the metals, as an alloy. Zinc is more readily deposited than copper and both of these metals are much more readily deposited than nickel. The percentage of copper in the deposit is relatively greater than the copper percentage in the bath. The nickel percentage in the deposit is relatively much less than the nickel percentage in the bath. The percentage of zinc in the deposit is more nearly the same as that in the bath.

Increase in current density favours deposition of zinc and nickel over copper. However, zinc deposits more readily than nickel with increase in current density. Increase in temperature causes an increase in the percentage of copper in the deposits. Increase in temperature causes relatively a greater decrease in the percentage of zinc in the deposit than the percentage of nickel. At about 50° C. there is a rearrangement of the factors controlling deposition. This causes a reversal in the slope of the curves plotted for the % copper and the % zinc in the deposit versus the % of these metals in the bath. The same effect is noticed upon the ternary curves giving the composition of the deposits.

The Institution of Mining and Metallurgy Bulletin.

The May issue of this Bulletin contains a report of the speeches at the recent annual dinner of the Institution. The speakers included, in addition to Mr. G. W. Gray, the President of the Institution; Mr. F. H. Hamilton, Sir Harold Carpenter, the President Elect; Sir Richard A. Gregory, Bart.; and Mr. H. T. Tizard, C.B., and while there is no doubt those present at this function had an enjoyable time these speeches are well worth reading by them as well as by those who had not the good fortune to be present.

This issue also contains discussions on two papers and a reply to a discussion on another paper. The paper by Mr. David Williams on "The Geology of the Rio Tinto Mines, Spain," has caused considerable discussion, which will be read with interest; the same applies to the paper on "The Relation between Width and Cost in Narrow Stopes," by Mr. James G. Traill. Those who have followed the paper by Mr. O. Davis on "Roman and Medieval Mining Technique" and the subsequent discussion, will be interested in the reply of the author. This issue includes the annual report of the council.

Rust-Proofing Processes.

With regard to the excellent article by Mr. O. W. Roskill on the above subject, which appeared in our last issue, mention is made under the sub-heading, "Metal Spraying," that the process is controlled in this country by the British Oxygen Co., Ltd. We have since been advised that the metal-spraying process is controlled in this country by Metallisation Ltd., while sole selling agents for plant are the British Oxygen Co. Ltd.

Internal Chills for Iron Castings.

Because of its higher coefficient of expansion, "Ni-Resist" (alloy cast iron containing about 14% nickel, 6% copper and 2% chromium), has been found to provide an important advantage for use as a solid internal chill in iron castings. When employed in this way, the material quickly reaches the approximate temperature of the surrounding metal before the latter solidifies. Since its expansion is about 50% greater than that of cast iron, the "Ni-Resist," upon cooling, contracts away from the surrounding metal and may easily be removed even if the chill is not tapered.

Some Recent Inventions.

The date given at the end of an abridgment is the date of the acceptance of the complete Specification. Copies of Specifications may be obtained at the Patent Office, Sale Branch, 25, Southampton Buildings, London, W.C. 2, at 1/- each.

Rolling Discs.

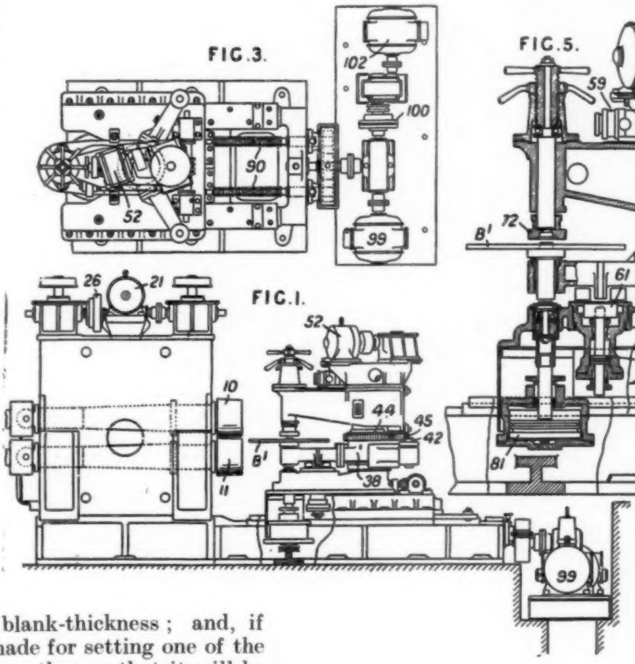
RECENT improvements have been effected in machines for rolling circular metal blanks or discs for use in the formation of vehicle wheels. In one improvement the machine comprises a pair of co-operating rolls which are supported at one pair of ends so as to leave the other ends free for the passage of the blanks. The rolls are arranged with their axes parallel and are made with profiles which conform with the varying thickness desired in the finished blank, and the blanks are automatically fed, one after the other, to the rolls and are automatically withdrawn.

Each blank to be rolled may be clamped, at its centre, between freely rotatable clamp plates, and these plates moved towards the rotating rolls, between which the blank is forced and progressively advanced while being acted on. The blank rotates while between the rolls and is reduced by them in thickness to its finished dimensions under controlled conditions.

Provision may be made for adjusting the distance between the rolls to suit the blank-thickness; and, if desired, provision may also be made for setting one of the rolls at a slight inclination to the other so that it will be possible to regulate with precision the sectional taper of the finished blank.

As shown in the accompanying illustrations, freely rotatable discs B^1 are gradually moved in radially to the bite of overhung rolls 10, 11 which roll and taper them. The disc holders comprise a 3-armed turret 38, at 120°, which is rotated through 120° at a time so that a disc can be placed on one arm holder 42, while the disc on the other arm is being rolled and the third disc is being removed. The turret is rotated from a motor, and 3 to 1 gears 44, 45 when the operator starts a one-revolution clutch 48 by allowing a pneumatic piston device 59 to withdraw a roller 57 from the scroll cam 56 so that the spring 54 raises one part of the clutch 48 to engage the other part 47 driven from the motor. The operator then reverses the device 59 so that the roller 57 presses against the rim of the now raised cam 56 until, after one-revolution, it can enter the drop 56*a* whereby the cam 56 lowers itself and separates the clutch sleeve 48 from 49. When a turret arm comes to rest it engages a stop 61 raised by a hand operated pneumatic piston 64, and the blank is clamped by hand operating a pneumatic piston 81 which raises and forces it against a fixed clamp 72. The clamp 72 has an initial screw adjustment. To feed the blank quickly towards the rolls, the whole turret-driving and adjusting mechanism is fed in gradually by feed screws 90, driven at first quickly by a high speed motor 99, and when the disc just enters the rolls the motor 99 is stopped, a magnetic clutch 100 is operated through which the slower motor 102 starts a slower feed of the blank, etc., while the rolls operate on the blank. On completion the motor 102 is declutched by hand and motor 99 is started in reverse to withdraw the turret and work quickly from the rolls. The clamp 41 and the stop 61 are lowered by their hand-operated pneumatic pistons and the turret is started on its rotation for the hand removal of the finished disc and feed of the next one. The roll pass is adjusted at one or both ends of motor 21 and gearing driving end screws; the drive to one screw can be uncoupled by a clutch 26.

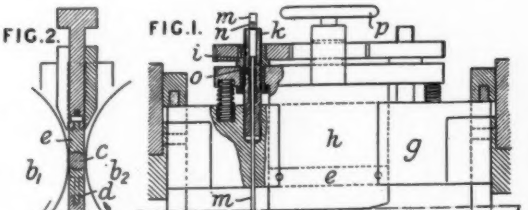
397,250. Colvilles Ltd., and T. W. Hand of Colvilles Ltd., Dalzell Steel and Iron Works, Motherwell, Lanarkshire. August 24, 1933.



Improved machine for rolling discs for vehicle wheels.

Gauging and Spacing Improvements in Rolls.

IN machines of the inclined roller type for the straightening and true rounding of bars it is necessary to guide the bar to be rolled between two work supports or guide rails, which determine its position between the two rolls of the machine. The distance between the guide rails is adjustable transversely to the plane of the rolls; accurate maintenance of this distance and consequently of the correct medial



Machine for straightening and true rounding bars.

position of the bar between the rolls is essential. Direct observation of the guide rail position, especially of the position of the lower guide rail, presents some difficulty. The position cannot be gauged by marking the rail driving mechanism on account of the heavy wear to which its slide edge is subjected.

According to the present invention a gauging device is provided in such a manner that one of the two screw bolts by means of which the guide slide of the top rail is adjusted has an axial bore extending through the slide carrying piece and that a measuring rod introduced into this bore may be lowered down to the upper edge of the bottom guide rail. The measuring rod has at its outer end a scale for reading off the depth of introduction. The said scale indicates the distance of the guide ruler from the centre line of the machine. In order to be drawn out of the path of the rolled stock during operation of the machine, the measuring rod may be provided with an upwardly acting spring.

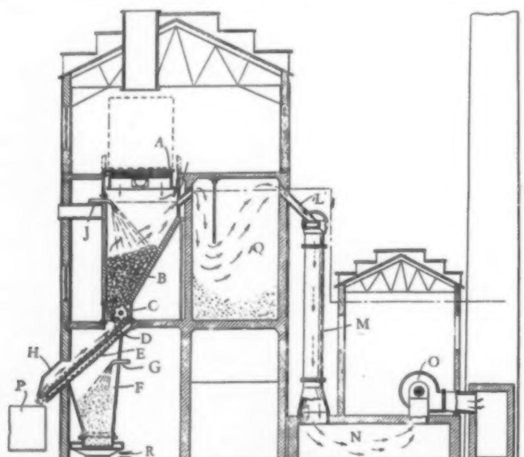
Figs. 1 and 2 of the accompanying drawing illustrate a construction of a gauging device according to the invention.

In straightening a rod *c* by skew rolls b_1, b_2, the rod being supported between guides *d*, *e*, the spacing of the guides is measured on the scale *n* of a feeler rod *m* sliding in the sleeve *k* of one of the spacing adjusting nuts *i*. The rod *m* is momentarily depressed by hand to touch the lower guide when a reading is to be taken, and when released jumps up owing to the spring *o*. The guide *e* is secured to a slide *h* movable in the cross-piece *g* and is adjusted up or down by hand-wheel *p*. The bottom guide *d* is also adjustable, by wedges.

397,298. Maschinenbau-Aktiengesellschaft of Saarbrucken, Germany. August 24, 1933.

Cooling Sintered Material

Freshly sintered material is practically red hot and, for convenient handling, its temperature must be reduced. For this purpose the passage of air through the mass does not sufficiently reduce the temperature, and another method has been developed which is claimed to be an effective means of cooling freshly-sintered material, and



Improved sintering plant.

also improves the collection of dust produced in the dumping operation. The object of this method is to provide efficient cooling without the introduction of a multiplicity of steps or complicated mechanism of any kind, and without the necessity of removing the material from the receiving hopper into which it is discharged. The method consists in dumping the freshly-sintered material into the receiving chamber, screening the fires from it, wetting the fires to reduce the temperature, and causing the steam generated to traverse the receiving chamber.

In the accompanying illustration, which represents a cross-section of the plant used with this method, the material discharged from a rotating pan A is received in a hopper B at the lower end with a crusher C, which feeds the material over superposed screens D, E, the fires which fall into the hopper F being cooled by water from a spray G, and the steam thereby produced passing, together with air entering the discharge hood H, upwardly through the mass of material in the hopper B. A second water spray J is fitted in the hopper B which communicates, through pipes at its upper end, with a partitioned dust-depositing chamber Q, the cleaned gases being drawn off through pipes L, flue M, and chamber N by a fan O which delivers them to the stack. The screens D and E deliver into a wagon P, while the cooled fires are discharged on to a conveyor R, which returns them to the raw material supply to be mixed with unsintered material.

395,619. J. E. GREENAWALT, New York, United States of America. July 20, 1933.

Impact Testing of Cast Iron.

THERE has been much controversy regarding the most satisfactory method of testing cast iron, and agreement has not yet been reached. One aspect of the subject is considered in this extensive report, which deals very comprehensively with several forms of impact test as applied to cast iron. The research work involved was carried out by Sub-committee XV. on Impact Testing, of A.S.T.M. Committee A-3 on Cast Iron, and the co-operation of prominent workers in the field of cast iron was enlisted.

The object of the investigation, which extended over a period of three years, was to determine the usefulness of the several forms of impact test, and some 500 test bars were specially cast, machined and tested by the several methods investigated, on the various types of machines commercially in use. Extensive tables give the results of the transverse, tension, fatigue, compression and shear tests which were made, and by the use of graphs these data are condensed in convenient form. Notched and unnotched Charpy and Izod tests were run, as well as repeated blow and drop tests. The conclusions of the committee in charge of the investigation show that the very small specimens, such as are used for steel, are not reliable indices of the impact strength of cast iron. Enger's modified Izod with a fairly large specimen is by far the best used, though there is no reason to believe the same size specimen should not give equally good, and perhaps better, results in a Charpy machine. The Krupp-Stanton test gave relatively enormous difference in results from irons closely approaching each other in all other properties. It is difficult to see how this test means anything when applied to cast iron. All notched specimens were unsatisfactory.

When using specimens 1·20 in. in diameter, the large pendulum machines of the Russell and Charpy type give results which follow closely the resilience measured in the transverse test. The drop tests seem to indicate the impact resistance left in the bar after previous loading to a point just below the breaking point. A drop test, therefore, considered in the light of the transverse resilience, would appear to be a useful index of the relative amounts of plastic and elastic deflection. The bending curve of the transverse test, if the test is accurately carried out, is capable of giving most of the information needed about cast iron, and the Brinell hardness determined over the whole cross-section is the most valuable supplementary test. The drop-test machines differ greatly in their construction, and the committee consider that they would probably become quite generally used, if the machines were carefully standardised in all dimensions. The tests would then give valuable corroboration to the results of the transverse tests. The committee does not recommend at this time any move towards an impact requirement in specifications.

Included in the report are discusser's comments, and also a chapter on the microstructure of irons in the investigation, which enhance the value of the publication.

Copies of the report, aggregating 51 pages, in heavy paper cover, can be obtained at 50 cents each from the American Society for Testing Materials, 260, South Broad Street, Philadelphia, Pa.

Business Notes and News

Developing Mufulira Copper Mines.

The Mufulira Copper Mines are situated in Northern Rhodesia, and plans for bringing the property to the producing stage were deferred because of the restriction of output scheme. Last October the mines were reopened and the plant has since worked satisfactorily. It is now proposed to equip the property for the treatment of two million tons of ore, producing 70,000 tons of copper a year. To provide funds for this programme the company have issued £1,000,000 5½% Debenture stock at an issue price of £101 %. This stock will be finally redeemed in 1966 at £102, the company having the option to repay in 1937 at £104½, in 1938 at £104, in 1939 at £103½ and in 1940 at £103.

So far the company has not made a profit, but the prospectus recently issued states that when 50% of the programme outlined above is completed the earnings will be sufficient to cover the service of these Debentures.

London Tin Corporation.

The report and accounts of the London Tin Corporation show a distinctly improved position, according to the annual statement recently issued. For the year ended September 30 last the net profit amounted to £60,335, compared with £44,050 for the preceding year, while the disposable balance is brought up to £248,272. This result is the more satisfactory, seeing that the recovery in the price of tin occurred only in the latter months of the year and is therefore not reflected in the year's profit. Proposals for dealing with the arrears of dividend on the Preference shares are made. The arrears up to September 30, 1933, amount to £265,644, and this has since been increased by £37,949 in respect of the half-year ended March 31, 1934, making a total of £303,593. The directors state that the accrued profit to date is more than sufficient to cover the whole of this sum, while since the close of the year the Corporation's liabilities on loan account have been practically liquidated, and contingent liabilities reduced to comparatively negligible proportions. They accordingly recommend the payment of the whole of the arrears in cash, but point out that the depletion of the Corporation's resources at this stage would tend to reimpose the strain which they felt throughout the period of depression, and which the directors have consistently endeavoured to correct. In order to consolidate progress, the directors propose to create and issue 500,000 new Ordinary shares of 10s. each, to be offered forthwith to all shareholders at 12s. 6d. per share in the proportion of one new share for every twelve shares held. The directors recommend this procedure, which will avoid any further substantial liquidation of investments at a time when the metal trade is reviving and the permitted production of tin is being increased, in order that the Corporation may derive the full benefit of the policy pursued in recent years.

New Alloy to Replace Nickel-chrome Resistance Alloy in U.S.S.R.

A Soviet engineer named Beletsky, of the Molotov Works in Perm, has discovered a new alloy consisting of iron, chromium and aluminium. He claims that the new alloy is capable of withstanding a temperature of 1,300 degrees. As nickel-chrome is able to withstand only 1,000 degrees, the new alloy will have a great bearing on the Soviet electrical industry.

Malaria, Course of Instruction.

A malaria course for laymen—engineers, planters, etc.—will be held at the London School of Hygiene and Tropical Medicine, commencing on Monday, June 25, 1934, at 10 a.m. The course will be under Sir Malcolm Watson, Director of the Ross Institute of Tropical Hygiene, it will last five days, and will finish on Friday, June 29. It includes instruction on mosquitoes and their habits, drainage and malaria control measures generally, illustrated by lantern slides, films, etc.

The Course is for planters, mining engineers, construction engineers and those in charge of labour in the tropics. It will also be of interest to all laymen proceeding to the tropics. Doctors and missionaries may also attend, but the Course is primarily for laymen. Instruction is given free, and application to attend the Course should be sent in as early as possible to the Organising Secretary, Mr. H. Lockwood Stevens, Ross Institute of Tropical Hygiene, Keppel Street, Gower Street, London, W.C. 1.

Birmingham Section of the British Industries Fair.

Since its establishment in 1915, the British Industries Fair has been held as one unit and at one time. In 1920 a Birmingham section for the heavier industries became a part of the Fair, and ran concurrently with the London sections in February. It has now been decided by a Committee set up at the Department of Overseas Trade that in future the Birmingham section is to be held in May, and in 1935 from May 20 to 31, the London divisions continuing to be held in February. The reasons given for the change are that visitors from overseas are more likely to come to England in May than in February, and that the weather will be more suitable for open air demonstrations of machinery. From the export point of view, the change should be to the advantage of the Birmingham section; but the Fair as a whole, the export side duly considered, is likely to suffer from the fact that Dominion, Colonial and foreign visitors would have to undertake long journeys twice a year to see all that there is to be seen. There will, it is held in some quarters, be a tendency to reject either the London or the Birmingham displays, and it would not surprise us if an agitation arose to make the date of the London sections synchronise with that of Birmingham.

Messrs. Ferguson, Pailin, Ltd., Higher Openshaw, Manchester, have been awarded the contract for the making and fitting of switchgear at the Manchester Corporation's Stuart Street power station. The value of this contract is stated to be about £140,000 and it will ensure three years' steady work. During the last few months this firm has secured two large contracts for switchgear; one from the Swansea Corporation, which is valued at about £35,000, and another from Messrs. Edward Lloyd, paper manufacturers, Sittingbourne, for £70,000.

Company to Produce Motor Spirit from Coal.

Negotiations have been completed for the formation of a limited company, with a capital of £1,000,000, to build plants in various parts of the country for the production of motor spirit from British coal. It is to be known as the National Coke and Oil Company, Ltd., and its twenty plants are to be at Belvedere, near London, Leeds, Edinburgh, Glasgow, Newcastle, Manchester and Cardiff. The formation of this company will be the culmination of between three and four years' extensive experimental and research work with a comparatively small plant on the Cannock Chase coalfield, where, by a process exclusive to the new company, motor spirit has been produced from coal and marketed since last September at the rate of 1,000 gallons a day.

Excepting the large concern of Imperial Chemical Industries at Billingham and various tar distilling companies, this Cannock plant has been the only place in the country where spirit has been synthetically produced from ordinary coal. The other plants are to be a duplicate of this one, and will be operated in precisely the same manner. The Cannock plant will continue as at present with no enlargements or additional facilities.

When the whole of the plants are completed and working to full capacity it is claimed that 20,000 gallons of motor spirit will be made from coal each day. In the process adopted the main feature is that in extracting the original oil from the coal the process avoids taking out the tars and pitches. Usually the crude oil from coal contains 80% tar and pitch. The coal oil produced by the Cannock plant is claimed to be 100% oil.

Railway Rolling Stock Exhibition.

It is expected that more than 20,000 people will visit the big exhibition of rolling stock being arranged by the L.N.E. Railway Co., at their constructional works at Doncaster at the end of the month.

In addition to members of the Corporation, invitations have been issued to the chairman of local public bodies. Directors of the Company will also be present. Special facilities are being offered to school children throughout the area.

The entrance to the exhibition, which is being staged in the Crimpsall sidings, is by way of Kirk Street, Hexthorpe, and special bus facilities are being provided by the Corporation transport department on both days. The exhibition will be opened on Saturday, May 26, at 12.30 p.m., by the Mayor, and will be open until 9 p.m. On the following day it will be open from 9 a.m. until 8 p.m.

Research on Steelwork Design.

A series of experiments, the object of which is to reduce the cost of erecting the steel frames which to-day form the basic structure of practically all our large buildings, are described in the second report of the Steel Structures Research Committee, which has just been issued by the Department of Scientific and Industrial Research. The work has been carried out in co-operation with the British Steel Work Association, and the report reviews work done since 1931.

At the outset it was recognised that the investigations would be complicated and laborious, and that spectacular developments could hardly be expected at an early date. Nevertheless, much ground has been gained. The committee's experimental work has emphasised the empirical nature of present design methods. As no criticism has ever been levelled at the safety of existing steel buildings, it is logical to deduce that such empirical methods leave room for considerable economy in material, and there is reason to believe that, as a result of the mathematical and experimental investigations, it will be possible to make suggestions for considerable improvement in efficiency of design.

How great the improvement may be is indicated by the fact revealed in the report, that the putting into force of the committee's recommendations for a new code of practice, drawn up in 1932, based on a survey of the then existing knowledge, has led to a reduction amounting to as much as 20% in the cost of steel work required for the kind of buildings to which it mainly relates. It is apparent that much ground has been gained as a result of these investigation, and it is claimed that if black bolts with the usual clearances could be used in the erection of steel frames instead of rivets, the process of erection would be considerably simplified and probably cheapened, and the noise of riveting would be avoided. It has not usually been considered desirable to employ them, because of the danger of slip taking place, and, for any important structures in which erection conditions make riveting difficult, it has been customary to specify turned and fitted bolts, which add considerably to the expense.

It was possible, the report adds, to obtain bolts made of high tensile steel which can be tightened up sufficiently to prevent slipping, but in order to do this a special spanner was necessary. This had been devised. A possible method of using this would be to erect with an ordinary spanner in the first instance, and afterwards tighten up with the special spanner.

It is indicated that the committee fully realises that the results of its researches, to be of real value, must be expressed in a form suited for ordinary practice. This practical end has not been reached, but the objective certainly seems within sight. In seeking it, it has been necessary to carry out a complete mathematical analysis of the distribution of the actual forces set up in a steel frame when under load, and to check the resulting formulæ obtained against actual experimental results. Professor Batho, of Birmingham University, is investigating the action of various types of beam and stanchion connections, and in the report he deals with the mathematical methods developed for the analysis of experimental data.

Work on wind pressure, now being carried out by the staff of the National Physical Laboratory under the supervision of the Building Research Board, aims at discovering, by experiments on models in wind tunnels, what shielding effect from wind pressure is given to a particular building by a built-up area. Since the horizontal forces due to wind pressure are the major complicating factor in a simplified design of steel-framed buildings, the results are awaited with interest.

Plans to Help British Shipping.

The Government's plans to afford assistance to the British shipping industry are nearing completion. It seems to be apparent that the two main proposals will be State guarantees for loans to provide for the construction of new ships designed for a specific purpose, and the granting of "fighting" subsidies for the limited purpose of aiding ships on routes on which there is direct competition with subsidised foreign lines.

Ministers have definitely rejected the proposal that the assistance they might give to the British tramp shipping industry should take the form of a general subsidy. They have also decided not to apply discrimination against foreign ships in the carrying of inter-Imperial trade.

Tin Quota.

At a special meeting of the International Tin Committee, held in London recently, it was decided that a quota increase, amounting to 10% of the standard tonnages, should be given in the four signatory countries, with effect from April 1, 1934, for a period of six months. This is equivalent to an increased production of 8,280 tons in six months.

In view of statements which have obtained wide currency to the effect that the proposed buffer stock will be built up from the normal production quotas, the Committee desire to point out that the tin required for any buffer stock will be provided entirely from a special quota which will be additional to the normal quotas.

Some Recent Contracts.

Hunslet Engine Company, of Leeds, have secured an order from the Chinese Purchasing Commission under the Boxer Indemnity Scheme for five locomotives. This order is valued at about £30,000 and is the second order the Company have received from the same source within a year, and as the latest engines will be similar to those built for the first order the company have promised delivery in five months. Four of the engines will be used on the Hangchow-Kiangshan Railway, and the fifth will haul the Nankin ferry train in conjunction with another Leeds engine.

The four passenger engines will be of the 4-8-0 tender type, the tenders being exceptionally large and with eight wheels. The ferry engine will be a tank type, the cylinder size being no less than 22½ inches.

Armstrong Siddeley Motors, Ltd., it is understood, have received an order from the German Government for 80 aero-engines. This firm produces a whole range of air-cooled engines from the five-cylinder type rated at 80 h.p. to the 14-cylinder Leopard, which yields 800 h.p.

An approach was made to the firm on behalf of the German Government in the middle of last year, but at that time the negotiations were not successful. Some time ago a small number of Rolls-Royce aero-engines were supplied for experimental purposes to Germany, but this is the first order of any size received from Germany by a British constructor since the War.

The Cambridge Instrument Company, Ltd., of 45, Grosvenor Place, London, S.W. 1, have received an order from Messrs. Improved Metallurgy, Ltd., Avonmouth, for a large and comprehensive equipment of temperature recorders, and indicators, for their new plant. The contract includes 20 potentiometric 4-point recorders and two 18-point indicators, all flush-mounted on four steel panels, together with a large number of thermocouples and several other instruments.

Messrs. William Gray and Co., Ltd., of West Hartlepool, have obtained a contract to build two paddle ferry steamers for the L.N.E.R. The vessels will be about 200 ft. long and designed to carry up to 1,200 passengers, private cars and cattle. They will be used by the L.N.E.R. to augment their passenger service from Hull to New Holland.

Messrs. Cochrane and Sons Ltd., Selby, have received an order for a super trawler for the Hull Fishing Fleet.

PERSONAL.

Mr. Leonard C. Burrill, one of the most promising of the younger naval architects on Tyneside, has been appointed assistant naval architect to the Manganese Bronze and Brass Co., Ltd., London. Mr. Burrill, who is only 28, served his apprenticeship at Messrs. Swan, Hunter and Wigham Richardson's shipyard, Wallsend, and won the firm's scholarship in 1922 when he was too young to proceed to the university. He later went to Armstrong College, Newcastle, and in 1927 took his B.Sc. (Honours) Degree, and was awarded the 1851 Exhibition Post-Graduate Scholarship in naval architecture on the recommendation of the Council of the Institution of Naval Architects.

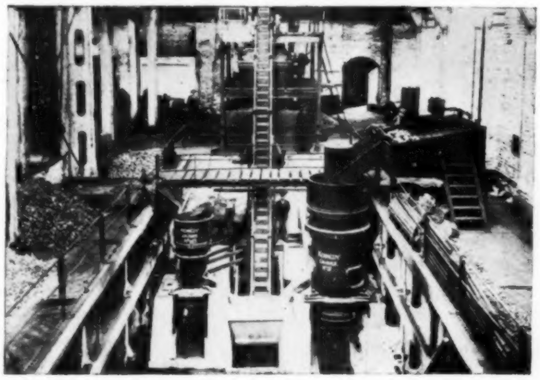
He then carried out research work on the seaworthiness of colliers, and made trips on vessels for about two years. His paper on the subject gained him the premium of the Institute of Naval Architects. In 1929 he was appointed assistant naval architect at Wallsend shipyard, and was later associated with the newly-formed Optimum Davit Co.

MODERN CRUSHING METHODS.

Plant for crushing limestone, ironstone, blast-furnace slag, and other materials is discussed.

THE ideal crusher for limestone, ironstone, blast-furnace slag and other material gives continuously, for long periods without adjustment and repairs, the crushed product always in the cubical shape. In this connection of great interest is a complete large scale crushing plant at the works of the Sheepbridge Coal and Iron Co., Ltd., Chesterfield, so arranged that any variety of material can be crushed in the bulk form to demonstrate the results. Quite apart from limestone and ironstone, all kinds of hard material have been crushed in the plant, including granite, Basalt-Olivene, gravel (Trent), flint, chert, whinstone, light-coloured whinstone, and syenite, to mention a few examples only.

This demonstration plant has two "Kennedy" crushers, No. "37" and No. "19" sizes, which are sunk in a pit, together with mechanical elevators and special vibrating screens for grading the crushed material discharging to various bunkers for easy weighing. The whole equipment is housed in a large building having a powerful overhead crane, and a complete equipment of scientific instruments is provided so that the speeds, horse-power, time for the crushing, and other detailed information can be recorded.



Demonstration plant of two gyratory gearless crushers and mechanical elevator at the works of the Sheepbridge Coal & Iron Co. Ltd.

The smaller No. "19" crusher requires 20 h.p. for driving and takes material of about $3\frac{1}{2}$ in. size, and reduces it to below $\frac{1}{2}$ in. in the cubical form, with the exception of 5–7% rejections, and the normal output, taking limestone as typical, is 15–20 tons of the material per hour. As regards the larger No. 37 in. machine, this takes 7 in. pieces and reduces them to $\frac{3}{4}$ in. or less if necessary, with a normal performance of 34 tons of limestone crushed per hour, requiring 40–50 h.p. It will be obvious such a performance represents very high capacity for low power consumption, as compared with many other types of crusher, quite apart from the material always being in the cubical condition.

It will be remembered from previous description in these columns the "Kennedy" crusher consists in the use of a relatively short, vertical, heavy steel spindle or shaft, carrying a manganese steel crushing cone, which is caused to move continuously in gyratory fashion within a manganese steel stationary throat, forming the crushing space. That is, the vertical shaft does not normally revolve on its own axis, although free to do so, but moves in gyratory fashion about a fulcrum at the upper part of the machine, above the crushing space. At the bottom the gyratory drive is given by means of a short foot bearing, in which the shaft rests, because it is fixed in the right position, off the centre, inside an outer high-speed vertical steel driving ring or pulley, driven efficiently and noiselessly by means of a belt, no gearing being used, another important advantage.

There is also provided at the top of the shaft a series of powerful springs, so that if any uncrushable material, such as a piece of iron, should be present, no harm is done, the vertical shaft moving downwards momentarily against the compression of the springs and allowing the material to pass through. The springs are of sufficient strength to resist compression during normal crushing, while to adjust the size of the final product all that is necessary is to alter the position of a large adjusting nut at the top of the machine, which moves the shaft in a vertical direction relatively to the throat.

Recommended Methods for Testing and Control of Foundry Moulding Sands.

It is now recognised by foundrymen that considerable saving can be effected in the cost of materials, by the regular and accurate testing of the moulding sand used. It has been repeatedly shown that accurate control of the sand which is made possible also has a distinct influence in improving the quality of castings, because such a practice results in the elimination of many of the troubles which result in faulty castings, such as low bonding strength, excessive moisture, low permeability, bad skin, etc. Controlled tests, however, also effect economies in enabling the foundryman to avoid the excessive use of new sand, and facilitate the use of sand from new sources, because a selection can be made according to merit and cost, without the need of a practical trial at the risk of disappointment and spoilt castings.

It was thought at one time that the chemical analyses of moulding sands was adequate, but it is now appreciated that this supplies only part of the required information. Moulding sand testing has been studied by many research workers, and various methods have been suggested. The British Cast Iron Research Association, for instance, has given considerable time to a careful study of the subject, and its Research Report No. 73, prepared in 1930, gave full details of the methods of testing foundry moulding sands for both research and foundry control purposes, which had been adopted in the work done by the Association over a period of five years. In view of the general interest in this subject, the Council made the report available to all interested and it rapidly went out of print. The present report, Special Publication No. 2, forms the second edition of this report, and is revised and enlarged. It deals with recommended methods for the testing and control of foundry moulding sands for any branch of foundry work. The bulk of the report consists in the procedure recommended for sampling, milling and compaction of moulding sands and recommended methods for determining moisture, particle size, the mechanical strength, permeability and refractoriness of moulding sands. A section is included on chemical analysis, and appendices are included on the principles governing the size of the recommended test pieces and representative results from all parts of Great Britain in various branches of foundry practice. A complete statement of recommended testing apparatus, with prices, is also included.

Foundrymen will find this Report of great value and it will enable them to arrange for the testing of moulding sands on a reliable and proved basis, which cannot fail in assisting towards the production of sound castings.

Published by the British Cast Iron Research Association, 21, St. Paul's Square, Birmingham. Special Publication No. 2, Price 10s. 6d. net.

The Butler Machine Tool Co., Ltd., Victoria Ironworks, Halifax, have issued a new sectional catalogue illustrating and describing their range of Openside Crank Planers, 24-in., 36-in., and 48-in. stroke. The demand for this special type of machine is rapidly increasing, and on account of the new and distinctive features incorportaed in these models, a copy of this catalogue will prove interesting and informative.

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N. Staffs Forge No. 4	3 7 0
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Foundry No. 1	3 10 6
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